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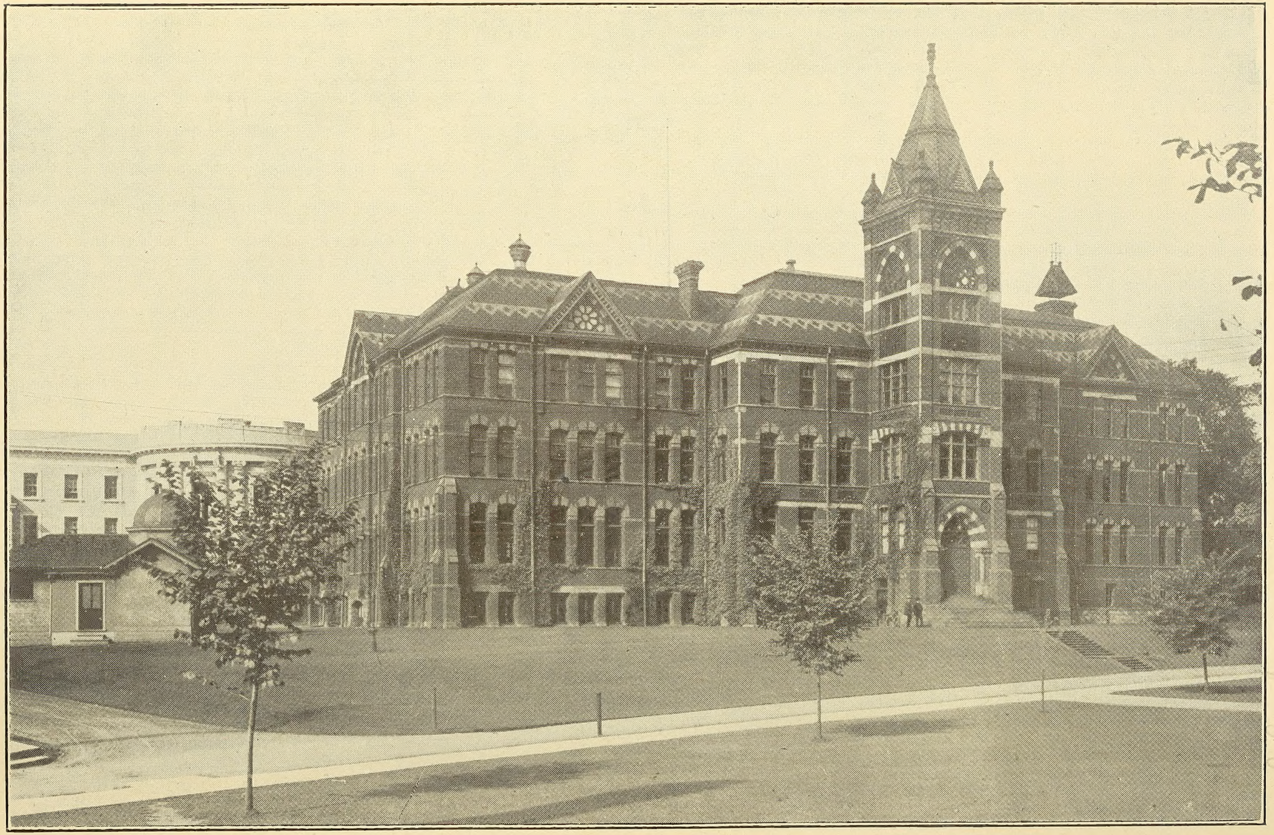

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THE GROUNDED NEUTRAL AS APPLIED TO TRANSMITTING AND DISTRIBUTING SYSTEMS

W G. CHACE, '01

The primary objects of grounding, in general, have been to save cost of complete metallic circuit; to prevent destruction of life and of apparatus. The first use of electric current was for the purposes of communication by telegraph, when low voltages were used and but one conductor was strung between the terminals of communication. Considering the high resistance of the metallic conductor used and the small amount of current involved, the ground return formed a very satisfactory portion of the circuit. This system was also applied to the earlier telephone circuits which had the field prior to the introduction of electric lighting distribution or of railway systems.

The ground return via the track rails, unbonded, and adjacent earth was used in connection with the earlier electric railway systems; and the grounded rail, thoroughly bonded, is now an element of the circuit of nearly all electric railway systems in use, both direct and alternating current.

In connection with the distribution of electric currents for lighting, the grounding of one side of the circuit was occasionally resorted to, but this practice was frowned upon by the insurance companies as likely to become a source of fire risk, but with the introduction of the (Edison) three-wire system of electric lighting in the days when direct current alone was used for this purpose, the practice of grounding the middle or "neutral" conductor was resorted to very freely; and when the use of the direct current was to a large extent superseded, and everywhere supplemented by the more convenient alternating current with its transformers, the Edison principle of three-wire circuits being made use of on the low side of the transformers, the neutral was at first permitted to be grounded, and during the last two or three years it has been distinctly urged by the insurance companies that it be grounded, with the double object of immediately discharging high voltage which may, through fault of the transformer, reach the low potential circuit, and of protecting life.

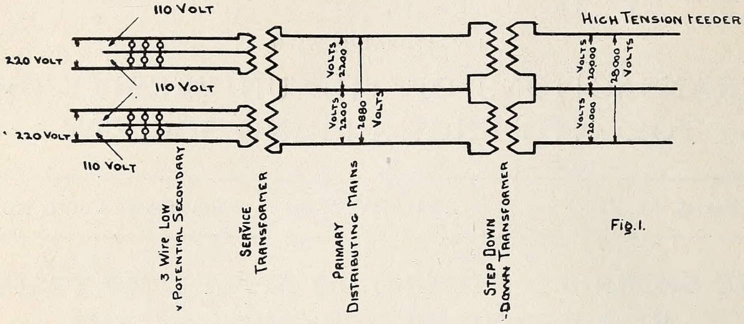


Fig. 1.

Here with all sections of the system indicated ungrounded, there is danger of the high voltage from the 20,000 volt mains crossing into the 2,000 volt circuits, as also of the 2,800 volts of the three-wire, two-phase, 2,000 volt (so-called primaries) transgressing upon the 220-110 volt secondaries; but with the grounding of the middle wire of the low potential secondary distributing circuit, there is little danger of disaster other than to the transforming equipment.

The reader is referred for a fairly concise discussion of the grounding of constant potential systems to a paper by Hood in the Electrical World for 1904, volume 43.

1. The neutral point is not always accessible in the ordinary equipment of transformers for high potential transmission or distribution. (See fig. 2.)

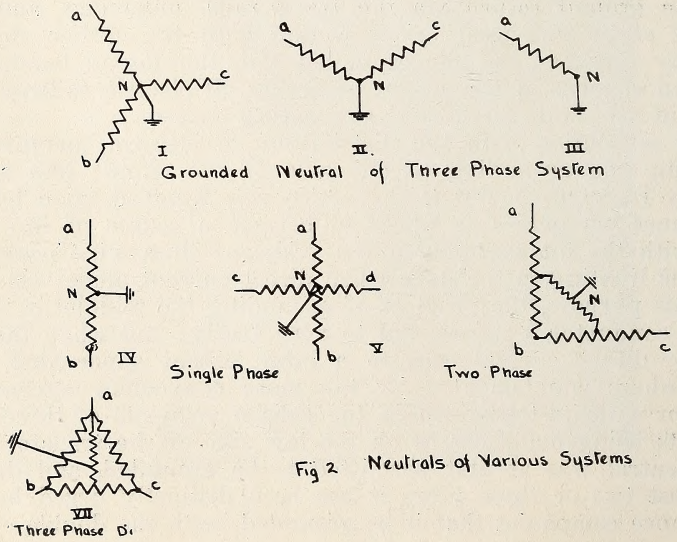


Fig 2 Neutrals of Various Systems

In a single phase transformer a special tap must be brought out from the middle point, but should it be desired to have a number of optional working taps at one end of the high potential winding, this middle point is not always the middle point electrically, but it would serve as a point at ground potential which could conveniently be connected to the ground. In a two-phase, four-wire system, the taps from the middle points of the single-phase transformers used could be joined together and to ground; but in two-phase, three-wire system it would be necessary to make use of an auto-transformer, tying together the middle points of the single-phase transformers, and from the middle point of this auto-transformer to obtain a point for grounding. In a three-phase star connected system the common point of the star serves conveniently for grounding, but in three-phase delta connection it is necessary to make use of an auto-transformer connected from the junction of two phases, for instance A and B to the middle point of phase C, from which auto-transformer at a point one-third of its winding from phase C a grounding could be made. This method of obtaining the neutral point from an auto-transformer is almost never resorted to on account of the expense of the auto-transformer.

The purpose of this paper is to place before the Society a summary of the readily available American literature on the principles and practice with regard to grounding the neutral point in transmission and distributing circuits.

The various objects to be served by the grounding of the neutral in high potential alternating current systems are:

1. (a) To maintain constant the potential of lines to ground, in order
   (b) to protect apparatus, and thus
   (c) to minimize the interruptions to the circuits, by
   (d) making possible detection and thus removal of undesired grounds;

2. To prevent abnormal static induction upon neighboring circuits;

3. To make the ground (return) available as a working conductor;

4. To make the condenser current per phase uniform, and thus to prevent high static voltages upon the circuits.

The above summary of the objects in grounding the neutral is largely taken from a paper given by Paul M. Lincoln in October, 1907 before the New York Section of The American Institute of Electrical Engineers.

In reference to 1 (a) and (b), it has been held by some that the grounding of the neutral, for the purpose of maintaining a constant difference of potential between each wire of the circuit and the ground, will permit the use of cheaper insulation, but it has been fairly well shown in practice that it is not the ordinary operating conditions and accompanying normal voltages which limit the insulation desirable or required, but rather the abnormal stresses set up either through induced changes on the line, or by the opening of circuits in switching, by breakage of a conductor, by accidental grounding, or through real short circuit. Mr. Gerry of the Missouri River Power Co. has pointed out that the earth resistance between grounds often throws full line potential on the line insulation. In this connection reference is made to a very complete discussion of the possible voltages, abnormal voltages and currents in high potential transmission as dependent in ordinary practice in construction upon the length of the line and upon the constants in the individual cases, all as described by Ernest J. Berg, of Schenectady, in a paper read before the Schenectady Section of the American Institute of Electrical Engineers on January 31st, 1907. Mr. Berg shows that for overhead transmission at high potential the instantaneous voltage rise due to the breakage of the circuit is per phase above ground potential, the quotient obtained by dividing the instantaneous value of the current in amperes by 325; and, conversely, that when high voltage be thrown upon a dead transmission line the instantaneous value of the current which flows is the quotient of the instantaneous value of the electromotive force divided by 325, i.e., for average value of inductance and capacity; he also draws attention to the fact that these current and voltage values may exist in grounded as well as ungrounded systems. Mr. Berg further shows that in case of a slight leak of current, through switches for instance, especially if that leak take place through an inductive path, that the potential of the conductors of the circuit above ground may be tremendous, and he therefore advises that in all high potential work the advantages of a grounded neutral be taken advantage of, and through a non-conductive path.

An important advantage in maintaining the normal potential of the conductors at a definite electric distance above ground lies in the fact that the to date accepted lightning arresters, which consist of a series of very small gaps in conjunction with non-inductive resistances, may be closely adjusted so as to relieve the line with moderate increments of potential, and thus serve most completely their protective function. For example, in a 60,000 volt three-phase circuit, ordinarily the potential of each conductor above ground is about 35,000 volts. Evidently, if the neutral of the system be not grounded, and one of the three wires should become grounded, the other two wires would immediately be raised to a potential of 60,000 volts above ground, so that with this class of circuit it is necessary that the lightning arresters should discharge with a potential above ground of say 75,000 volts, whereas with the same factor of protection in a system with grounded neutral the lightning arresters could be adjusted to about 45,000 volts to ground, and destructive voltages would then be prevented from appearing upon the circuit.

In this connection it is desirable to read carefully a very thorough discussion by Mr. J. S. Peck before the American Institute of Electrical Engineers at Niagara Falls, N.Y. on July 1st, 1903. Mr. Peck shows with very great completeness the possible voltages likely to appear on account of the accidental grounds on one conductor, in circuits with grounded and ungrounded neutrals. This discussion of Mr. Peck's is very well illustrated and rather clearly set forth, but it must be kept in mind that a considerable number of the combinations which are analysed by Mr. Peck are for various reasons undesirable, and therefore almost absolutely unused. Such, for instance, as the YY connection of the transformers, excepting where the neutral of the step-up Y is connected to earth, not only at the transformer but also at the generator.

With reference to 1 (c) and (d), the attention will be drawn below to the experience of a number of companies, which have been operating, transmitting and distributing systems, some with and some without grounded neutrals. It has been found that with most systems the faults most commonly appearing is a grounding of one conductor. Should the other conductors of the circuit be in such proximity to the faulty conductor that the fault can communicate itself to one of those conductors, a short circuit between phases immediately results, and the full power of the generator, or of several generators, if operating in multiple, is concentrated upon the fault, and considerable destruction follows. Now, with the neutral of the transmission system grounded, the first ground which commonly has a path of considerable resistance, indicates itself in the station as a short circuit of great or little intensity upon the transformer forming that phase, or upon the generator if no transformers intervene, and if the resistance of the fault be sufficiently low automatic switches will open the circuits and relieve the trouble. A careful examination of the results, some of which are outlined below, of operating distributing systems with grounded neutral would seem to indicate that by this means the severity of the disturbances due to accidents on the circuit, and the destruction of the conducting system by these accidents is very materially reduced, so that the minimizing of the delay in resuming the use of the injured circuit is a very material gain, where continuity of service is so important, as it is in all systems supplying a high-class load, especially in large centres of population.

On the contrary in many systems, especially those whose circuits are wholly aerial, it is considered to be very undesirable that every ground should be a short circuit which, in operating automatic devises, interrups the service. Frequently an operator will prefer to risk damage to his apparatus rather than surely cut off his customers, when he knows that even with one conductor grounded he can continue to serve, in the meantime arranging for the removal of trouble indicated by his detectors.

2. Generally speaking, there are two classes of interference with neighboring circuits such as telephone and telegraph cir-

cuits, which interferences are due to the operation of high potential alternating current systems. These are those of electrostatic induction and electromagnetic induction. In the ordinary three-phase circuit there is an almost balanced series of static charges of elecricity on the conductors as against ground, the air acting as the dielectric of a condenser. Without a grounded neutral an accident grounding of one line of the circuit very seriously unbalances this system of static charges, and upon other metallic circuits within the range of the transmission circuits there appear a very considerable series of static charges also as against ground, sometimes sufficient to prevent the satisfactory use of those parallel circuits. The grounding of the neutral of the transmission circuit will prevent very serious electrostatic disturbances upon parallel circuits.

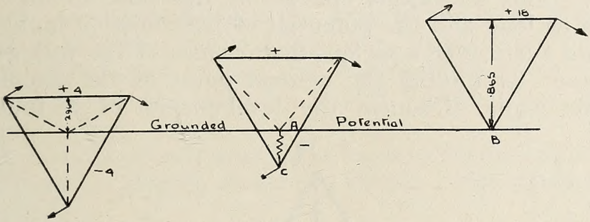
The electromagnetic effect of a high tension transmission upon parallel circuits is not materially influenced by the grounding of the neutral unless the earth carry current, as it would if used as indicated above in fig. 2, II and III. While ordinarily in an insulated circuit the electromagnetic effect upon parallel circuits is negligible, if the earth be acting as an element of the power circuit, the inducing loop bounded by the other conductors and the earth, being of a large area and dissymmetrically located with relation to the influenced circuit will set up very considerable electromotive forces in that circuit. Here the grounding of the neutral is a disadvantage, whose weight must be considered.

A clear discussion on this subject of the influence of power circuits upon parallel ones is to be found in the transactions of the American Institute of Electrical Engineers in papers by P. M. Lincoln in 1903.

3. The ground is some transmission systems commonly made use of as a working conductor in connection with the grounded neutral on the high tension side of the step-up transformers. In certain thinly populated districts where loads are sparse and small, the requirement of electric service can be met by use of the cheapest methods of construction. A single wire or, in cases of larger power, two wires of a hree-phase star connected system can be run out to the site of the customer's premises, and fairly satisfactory results can be had.

4. In the discussion by E. J. Berg above referred to it is shown that the lack of a ground at the neutral point is sufficient under the conditions of a ground on one conductor of the high tension circuit to set up very serious potential stresses between the generator windings and ground. A discussion of this source of troubles in generator and transformer windings is found in the *Electric Journal* for 1907, page 646, and in the same magazine for 1908, page 84, in papers by R. P. Jackson. (See Figs. 3 and 4.)

Briefly, Fig. 3 represents by a rotating triangle, first, the static condition existing normally, in which case the total charge to the ground is zero, and no current need be supplied from ground; second, the conditions existing in the case of a high resistance path to groundbeing established, in which event considerable current flows to the circuit through the fault; third, the conditions existing in the case of a "solid" ground, or one of zero resistance. In this latter event, with no grounded connection on the system, the effect is as indicated in Fig. 4. The transformer bank windings and the generator form two condensers in series, across which the static potential is divided in inverse proportion to their capacities, so that in case all windings be insulated from ground, and if the capacity of the generator windings to ground be small in proportion to that between the transformer windings, as would be the case for one generator operating on several paralleled banks of transformers, the stress of potential on the generator windings might puncture their installation. This condition of affairs can be avoided by grounding the neutral point of generator windings, preferably through a low resistance as suggested in Fig. 4.



Conditions Normal High Reistance Ground Solid Ground

Fig 3

Static conditions in Three Phase Delta Circuits

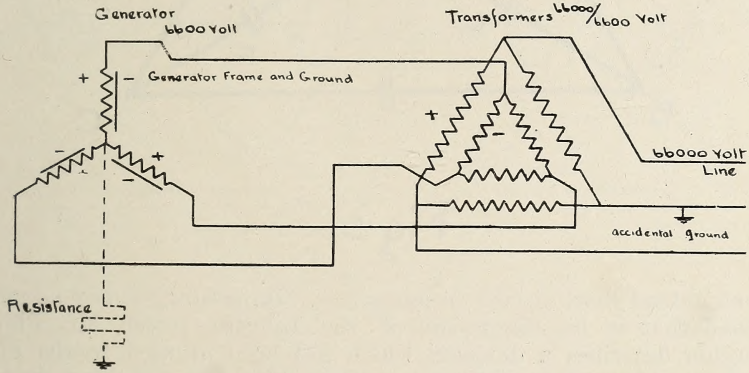


Fig 4

In Fig. 5 (taken from the paper on "The Grounded Neutral," by P. M. Lincoln, presented before the American Institute of Electrical Engineers at New York in September, 1907, is shown diagrammatically the magnitude of the capacities existing between lines and between the lines and ground in a three-phase system. With the lines thoroughly insulated from each other and from earth, and with neutral grounded or ungrounded, the currents flowing through capacities C are equal and their sum is zero. The sum of the kilovolt amperes in these paths is proportional to the product $3\,(C\,E)\,E$ or $3\,C\,E^2$, where E is the potential to earth. With the neutral ungrounded, and with a fault of zero resistance on one high tension conductor, the sum of the kilovolt amperes in these condensers is $2\,(C\,\sqrt{3}\,E)\,\sqrt{3}\,C$ or $6\,CE^2$. This is serious change in the state of the current if the lines be long and the potential of transmission high, and the result would further be a serious disturbance of the voltages in the three phases. Grounding the neutral point of the circuit would prevent this, while, of course, the development of a fault would mean a dead short circuit on one phase. In passing, it may be mentioned that in his discussion of the Lincoln paper, Mr. Philip Torchio describes a detector which has been applied to the high tension cable feeders of The New York Edison Co.'s system, and in which device this disturbance of capacity currents is made use of to indicate the presence of trouble.

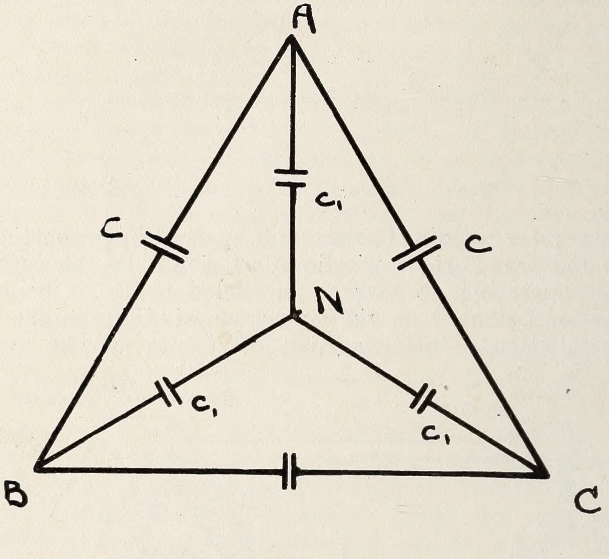


Fig 5

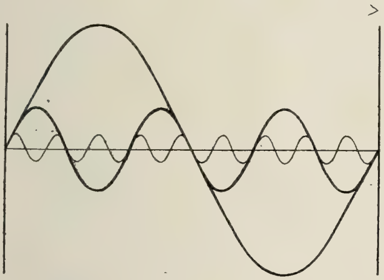
5. The method of grounding the neutral lead has been the subject of very considerable difference of opinion. All are agreed that to be effective and safe, the ground connection itself must be good; its resistance must be low and uniform, and it should preferably be kept continuously moist. But whether to use definite resistance

in the ground lead, whether to ground the neutral at more than one place, and whether to ground each generator unit or no has been much disputed. The discussion of this subject at New York in October, 1907, following papers before the American Institute of Electrical Engineers, by Messrs. Lincoln, Rhodes and Clark, was quite illuminative.

It was generally accepted that the connection to earth must be made with a minimum of inductance; it is fairly clear that the resistance in the path to earth must not be high, otherwise when current flows in the neutral lead of magnitude sufficient to influence automatic protective devices, the drop of potential therein will be so great as to defeat the end aimed at, namely, the prevention of abnormal differences of potential between the earth and ground. Some operators make use of a "solid" ground, i.e., one without reistance.

The resistance used must be or large carrying capacity, of uniform dimension, and mechanically strong. Iron grids have served satisfactorily.

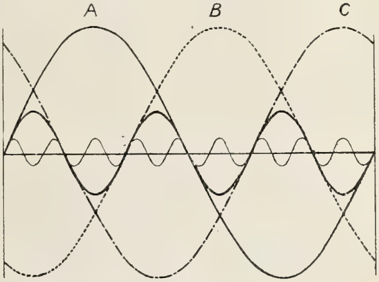
Attempts have been made to ground each generator of a bank operating in parallel, but the cross currents in the neutral lead have been such as to make this method very unsatisfactory, and in some cases unworkable. The explanation of this feature is made easier by a reference to Figs. 6 to 10.



PHASE A

3D AND 9TH HARMONICS

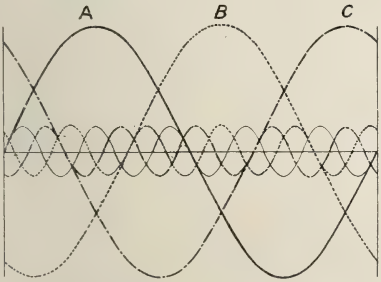
FIG. 6



THREE PHASES

3RD AND 9TH HARMONICS IN PHASE

FIG. 7



THREE PHASES

5TH HARMONICS OUT OF PHASE

FIG 8

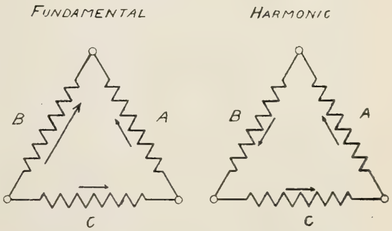


FIG. 9

In Fig. 6 is shown a fundamental wave of potential, and its third and ninth harmonics; in Fig. 7 are shown the fundamentals of three phases with their third and ninth harmonics. It will be noticed that these harmonics are in phase for the three phases; as drawn the harmonics are at zero coincidently with the fundamentals, but this is not necessarily or even probably true. In Fig. 9 are shown the relations of the fundamental and of the third harmonics at a given instant in the windings of a delta connected generator. It will be noted that the third harmonic does not appear outside the generator windings, but sets up a circulating current in the windings. In Fig. 10 are shown the relations of the fundamental and of the third harmonics at a given instant in the windings of a star connected generator. As these harmonics are in phase, they neutralize each other, and do not cause a flow of current in the outside circuit. However, should the neutral of this generator winding be connected to ground in parallel with that of another star wound generator connected to the same working bus bars, there would be an interchange of currents of triple and multiples of triple frequency between the generators, unless, as is unlikely, the phase relation and amplitudes of these harmonics be identical. It may be noted that it has been reported that certain steam turbine driven generators have been so connected without interchange of currents via the neutral leads. A full development of these conditions is given by Mr. A. G. Grier, of Montreal, in the *Electric Journal* for 1907, page 189, from whose paper these diagrams have been taken by his courtesy. In Fig. 8 is shown the non-coincidence of the fifth harmonics of the three fundamental waves of electro-motive force. These harmonics, along with other harmonics of a frequency described by an odd prime number, may appear in the external circuit to modify the form of the wave of electromotive force between main conductors.

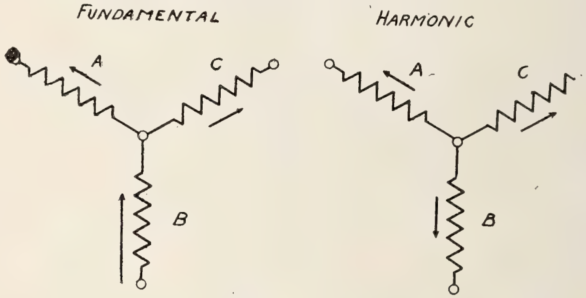


Fig. 10

6. The literature dealing with the experience of operating companies with the grounded neutral, covers chiefly systems distibuting power in large cities by means of underground and overhead circuits. Those reported most fully are that of the Interborough Rapid Transit Co. of New York City; that of The Long Island

Division of the Pennsylvania Railroad System, and that of The Commonwealth Edison Co. of Chicago; that of the Cincinnati Gas and Electric Co. has been reported briefly. The latter two companies have been operating with the neutral grounded since 1900, and Mr. Eastman, in speaking in 1904 of the experience of the Chicago company, stated that the advantages of having fixed the maximum potential above ground, and of the ease of locating trouble on the circuits, overbalance the dangers due to the fact that an accidental ground on one phase is equivalent to a short circuit. That company have both overhead and underground high tension lines.

The Interborough Company have operated since 1905 with a grounded neutral. Previous to that year their experience had been that nearly all faults in their distributing system appeared, first, as a "ground," afterwards developing into a short circuit after the flow of charging current through the fault had destroyed the insulation of the feeder cable. The evidences of trouble were usually discharges of "static" electricity at the substation or power station end of the cable, often unnoticed until the short circuit opened the feeder switches. This happened with considerable violence, sometimes resulting in the destruction of the switch. The rush of current back into the fault from the rotaries in the substation often opened all feeder switches and shut down the station. It was usually very difficult to locate the trouble, and much time was lost in so doing; this difficulty arose through the amount of destruction accomplished at the fault. Since grounding the neutral of the system, it has been found that a fault in the feeder cable usually cut out the cable quietly and little destruction of cable was wrought by it, so that it has been possible to soon get the cable back into service, repaired. For details of the experience of this company with and without the grounded neutral, see Rhodes' paper before the American Institute of Electrical Engineers, October 11th, 1907.

Grounding was done through a resistance of large current capacity, and of sufficient magnitude to limit the current flowing through the fault. At first all generators were connected to the neutral bus, which, in turn, was earthed; but the interchange of currents of triple frequency through the leads to the neutral bus was so great an annoyance that now but one generator in each of their two stations is grounded.

The New York and Long Island Railroad Company have had in operation an 11,000 volt, three-phase system, partly overhead and partly underground, for about two years. The neutral of this system is grounded through one generator lead with a resistance of 6.7 ohms. Their experiences are described in Mr. Clark's paper, read before the American Institute of Electrical Engineers on October 11th, 1907. It is declared to have been successful, but certain disadvantages are indicated to accompany the use of a resistance in the neutral lead, chief of which are that on occasions the current through the fault may be so small that it will not open the switch in the faulty feeder, and that the drop of voltage across this resistance is so great as to make the potential of the other conductors of the circuit to ground very great.

The practice of the Commonwealth Company is described by Mr. P. Junkersfeld in his discussion of the above-mentioned papers. This company operate two classes of high tension service, a four thousand volt, four wire, three-phase, sixty-cycle system of power distribution with neutral grounded without resistance, and a nine thousand volt, three-phase, twenty-five cycle system between generating stations and substations, part solidly connected to ground, and part through a resistance of 0.5 ohm. Their circuits are partly overhead and partly underground. The writer closes his remarks with the following:

"Our investigation and experience with one system for five years, and another system for seven years, leads us to believe, that between operating with the neutral grounded or not grounded under our conditions, the grounding of the neutral is the better policy. As to whether or not any additional benefits would be secured by grounding the neutral through a resistance, we feel that our experience is still too limited."

The New York Edison Co. have a 6,600 volt three-phase, twenty-five cycle, ungrounded system. Their electrical engineer, Mr. Philip Torchio, gives in his discussion of the Rhodes and Clark papers a detailed analysis of all the high tension cable faults on this system for the period between November, 1898, and October, 1907. He says: "Furthermore, in every instance when we had a burn-out or disturbance of any kind, we fully investigated all attendant circumstances, and tried to figure out how the results might have been modified by having the neutral grounded. In no case of cable burn out did we find that the results might have been sensibly improved by the presence of the grounded neutral."

The arrangements of a company, taken to be the New York Central and Hudson River Railroad, are described by Mr. Carl Schwartz. This company is operating now one large power station at 11,000 volts in connection with the recent electrification of their New York terminals. They purpose using several resistances of 19 ohms each, one in the neutral lead of each generator.

Dr. C. P. Steinmetz sums up the matter, as it appears to him, in the following sentences:

1. The neutral of the three-phase system should not be grounded where grounding is not necessary.
2. The neutral should be grounded if the system cannot be operated safely when electrostatically unbalanced.
3. Whenever it is not necessary to have more than one ground on the system, it is desirable to ground the neutral at one place only.
4. Whenever it is not safe to ground without resistance, resistance should be used in the ground circuit.

A considerable number of companies operating distributing systems in America, and very many in Europe, have adopted the three-phase, four-wire method with neutral grounded. One of the chief objects of the grounding of the neutral is the protection of the service transformers scattered upon the high tension mains.

The experiences related above with a grounded neutral have been those upon systems operating high tension generators. Many of the long distance power transmissions in America ground the neutral point on the high tension side of the transformers. Among these may be mentioned several portions of the systems of the California Gas and Electric Corporation, the extensive system of the Telluride Power Co. in Utah, and that of the Guanajuato Power and Electric Co. in Mexico. Mr. F. G. Baum, in his article on "High Potential Long Distance Transmission and Control," at the International Electrical Congress of 1904, with reference to the system of the California Gas and Electric Corporation, says in part: "Our general practice is to generate at 2,300 volts and step up to the line voltage, the primary of the transformers being connected star with grounded neutral. I have come to believe the grounding of the neutral to have more advantages than disadvantages. We take advantage of the grounded neutral, and very often instal a single transformer in a substation, one side going to line, the other to ground, where the load is larger but does not warrant three transformers, we put in two, using two legs of the primary and open delta on the secondary. We are not bothered with any unbalancing of load at the power houses."

In discussing the October paper on this subject, Mr. Baum further says: "A number of years' experience with several large transmission systems operating at voltages from 10,000 to 75,000, both delta and star, demonstrate that where the systems are properly installed there is no more difficulty in operating one than the other. Most of the troubles of the early transmission systems came from lack of insulation; with improvement in insulation there disappeared nearly all the troubles variously ascribed to 'static charges,' 'lightning,' 'ground currents,' 'telephone and telegraphic interference,' etc."

"For very high voltage systems I see no reason for adopting anything but a star connection."

Dr. F. A. C. Perrine, in a paper on "American Practice in High Tension Line Construction," read before the International Electrical Congress at St. Louis in 1904, made the following statement: "In general it may be stated that up to 25,000 volts the delta connection is generally preferred, principally because with this connection a ground upon one line does not necessarily result in a short circuit, and, furthermore, the service is not necessarily interrupted in the case of the failure of a single transformer. At voltages higher than 25,000 volts the transformers for delta connection become more difficult to build and insulate. Furthermore, a single ground anywhere produces disturbances of a serious character, and in consequence the star connection with the grounded neutral is employed, advantage being taken of the fact that a grounded neutral aids in the distribution of unbalanced loads, and, furthermore, the rise of pressure which may occur from line discharge at the time of open-circuit or a short-circuit are not so likely to produce serious results."

In conclusion it may be said that the subject, along with related matters with which it is involved, is so tremendous that justice cannot be done to it in any lecture or magazine article. The patient accumulation of the results of the experience of operating on systems will, with careful analysis, serve to guide the designers of transmission systems in the choice between grounding and not grounding, as dependent upon the special conditions of the case in hand.

PARTIAL BIBLIOGRAPHY OF LITERATURE DEALING WITH SUBJECTS RELATED TO THAT OF THE "GROUNDED NEUTRAL."

F. O. Blackwell, "Y or △ Connection of Transformers." Trans. A.I.E.E., July 1, 1903.

C. P. Steinmetz, "High Power Surges in Electric Distribution Systems of Great Magnitude." Trans. A.I.E.E., June 19, 1905.

P. H. Thomas, "An Experimental Study of the Rise of Potential on Commercial Transmission Lines, Due to Static Disturbances, Caused by Switching, Grounding," etc. Trans. A.I.E.E., June 19, 1905. "Grounded Neutrals with Series Resistances," *Electric Journal*, Vol. III., p. 484.

H. G. Stott, "Incidents in the Operation of a Large Power Plant and Distribution System." *Electrical Journal*, Vol. II., p. 278.

C. W. Ricker, "Experience with Grounded Neutral in High Tension Plant." *Electrical Journal*, Vol. III., p. 507.

R. P. Jackson, "A Peculiar Static Trouble." *Electric Journal*, Vol. III., p. 646.

A. G. Grier, "Circulating Currents in Three-Phase Generators." *Electrical Journal*, Vol. IV., p. 189.

C. F. Scott, " The Grounded Neutral." *Electric Journal*, Vol. IV., p. 662.

G. N. Eastman, "Harmonics in Three-Phase Circuits." *Electric Journal*, Vol. IV., p. 361. "The Grounded Neutral on Three-Phase Alternating Current Systems." Nat. Elec. Lt. Assa., 1904.

G. N. Eastman, "Protection and Control of Large High Tension Alternating Current Distributing Systems." Trans. Int. Elec. Congress, St. Louis, 1904, Vol. II., p. 518.

Humann, "Annual Savings by Use of Grounded Neutral." *Elek. Zeit.*, May 5, 1904.

E. J. Berg, "Line Constants and Abnormal Voltages and Currents in High Potential Transmissions." Trans. A.I.E.E., January 31, 1907.

P. M. Lincoln, "Transposition and Relative Location of Power and Telephone Lines." Trans. A.I.E.E., March 27, 1903.

P. M. Lincoln, "The Grounded Neutral, with and without Series Resistance in High Tension Systems." Trans. A.I.E.E., October 11, 1907.

G. I. Rhodes, "Experience with a Grounded Neutral on the

High Tension System of the Interborough Rapid Transit Co." Trans. A.I.E.E., October 11, 1907. "Neutral Currents of a Three-Phase Grounded System." *Electrical Journal*, Vol. IV., p. 382.

F. G. Clark, "The Grounded Neutral (Experience on the Distributing System of the Long Island Division of the Pennsylvania R.R.)" Trans. A.I.E.E., October 11, 1907. Discussion on papers read October 11, 1907, by Messrs. Junkersfeld, Torchio, Steinmetz, and others.

C. P. Steinmetz. Trans. A.I.E.E., 1901.
A. E. Kennelly. El. Wld. and Engr., 1901.
J. D. Nies. El. Wld. and Engr., 1902.
P. H. Thomas. Trans. A.I.E.E., 1902.
G. N. Eastman. Western Electrician, 1903.
David. Societe Int. des Electriciens, 1904.
Blonden. Societe Int. des Electriciens, 1905.
Brylinski. Societe Int. des Electriciens, 1905.
G. H. Parchell. Institution of Elec. Engrs., 1905-6.

Bibliography by Mr. Philip Torchio in discussion of Rhodes and Clark papers.

SOME NOTES ON MAINTENANCE OF WAY

G. HOGARTH, '09

BALLAST.

The ballast is a most important item in securing a good track and economy in maintenance and operation. The material should, if possible, be carefully selected, as it may have a decided effect on locomotive and car maintenance, as well as on the traffic. A dusty ballast will cause greatly increased wear on the journals and motion and on roads with extensive passenger traffic it is absolutely necessary to avoid dust and dirt by the use of good clean ballast.

The object of ballast is to distribute the load over the roadbed, to hold the ties in place horizontally and provide efficient drainage around and under them, so as to prevent freezing up in winter, to afford a means of keeping the ties truly up to the grade line, and to give elasticity to the roadbed. This is a statement of a perfect ballast and the value of the different kinds depends on the extent to which they fulfil these requirements.

This perfect ballast is never the most economical for all roads, as light traffic justifies something cheaper, but here the common error of using a very cheap ballast creeps in.

A railroad causes great discomfort to its passengers, and wear and tear on the journals of the cars and engines, where a little additional expenditure to provide a more suitable material would have made it a more pleasant road to ride on, and been much more economical to maintain.

The materials most commonly used are cinders, slag, gravel and broken stone, and in some cases, where these are hard to obtain, earth is used and called mud ballast.

Where the natural soil is gravelly and the water will drain through it quickly, it will make a fair roadbed for light traffic, but since this condition seldom, if ever, exists for a great distance, and since a heavy rain will spoil the results of weeks of patient surfacing of the track, it is seldom economical or satisfactory to use mud ballast if there is a gravel bed or other sources of ballast anywhere on the line of the road.

A liberal depth of ballast should always be allowed About 18″ below the tie is an excellent depth, but is very seldom used. Twelve inches should be a minimum depth, but very frequently this is cut down, and we find only 8″ to 12″ of ballast between the bottom of the tie and the upper surface of the roadbed.

CINDERS.

Cinders defined as the residue from the coal used in locomotives or other furnaces are only used as ballast after the road is in operation. They make a cheap and serviceable ballast, are easily handled with a shovel, prevent weeds growing, and being porous give excellent drainage. They are used extensively in yards and sidetracks on branch lines, where they will last for some time under light traffic, and are very useful in wet places, where the frost tends to heave the track. In some yards earth ballast is first used, and as the drainage is usually poor, a wet track results. The ties soon get loose and work up and down in the liquid mud. A good remedy for this is to dig out the wet spot, put in a good layer of cinders as ballast, and then lift the whole track several inches. For washouts cinders are frequently made use of, as several carloads, if necessary, can be quickly sent to the break in the track, and the damage repaired. Because of their good draining qualities cinders are preferable to gravel in yards, but as ballast on main line they are very objectionable, on account of the clouds of dust raised by passing trains in hot weather.

SLAG.

Furnace slag, or cinder, is extensively used on roads in the vicinity of blast furnaces and iron works. It is as durable as broken stone, and furnishes an excellent ballast, free from dust and perfect in drainage qualities. It is sometimes said that ties decay and spikes rust more rapidly in some kinds of slag ballast than in stone, but if properly drained the difference is slight. Slag gives excellent results; it keeps the track in good line and surface, and does not heave as much as gravel. It has been used by one large road for about twelve years, and has been very satisfactory and economical. That road arranged with the furnace company that the slag was to be poured from the pots down an incline 30 to 40 feet, when the slag cools rapidly, and has the appearance of broken china instead of the porous sponge-like appearance of slag handled in the ordinary way. It is also extensively used in England, where it is run from the furance on to a travelling belt, and suddenly cooled by water, which hardens it and breaks it up at the same time.

GRAVEL.

Gravel is the most common form of ballast that may be called good ballast. For light traffic, or on a busy main line, where a better but more expensive ballast is out of the question, or on a road where dust is not objectionable, it is most satisfactory and economical. Its good qualities are, it is easily worked, provides good drainage and keeps the track in good surface. Where the prevention of dust is desirable the gravel should be screened or washed. The screen used should have a ½″ mesh, so as to get rid of all dirt and the finest stones, but on account of the added expense it is seldom subjected to this treatment.

Gravel pits are not very common in Ontario, and where a good one is found near a railroad it is purchased, a steam shovel put in and the ballast sent wherever needed. The greater part of our railroad mileage is ballasted with gravel, and wherever used it is found satisfactory.

ROCK AND BROKEN STONE.

Rock or broken stone is in general the best material for ballast, as it meets all the requirements. The stone used should be durable enough to resist the disintegrating influences of the climate where it is used, hard enough to prevent pulverizing under the treatment to which it is subjected, and should break in angular pieces when crushed. The maximum size of pieces should pass through a screen having 2″ holes, but with regard to the minimum size, there is a variance of opinion. Some say the minimum size shall not pass through a screen having ¾″ holes, while others say that by having pieces that will pass through ¼″ holes the ballast sets quicker and requires less packing to make it firm. Rock ballast does not freeze solid, nor heave in cold weather; it can be worked in wet and dry weather alike; it becomes compact when in the track, has little or no dust, will stand hard tamping with a tamping bar; is one of the best ballasts known to shed water, and gives a longer life to the ties.

The best rocks for ballast are granite, trap and limestone, and the broken stone should be handled with forks, so as to avoid getting dirt and dust mixed up with it. This kind of ballast is more expensive than any other, but under heavy traffic will keep its surface better, and will require less work for maintenance than any other after the ties have once become thoroughly bedded.

The manner in which the ballast is distributed along the track is generally by means of specially constructed cars, which may have either side doors or centre doors. In the case of the side doors a large gang of shovellers, or a ballast plow, is necessary to clear the cars. If a ballast plow is used, it is put at one end of the train, and a steel cable is run from it over the cars to a winding engine at the other end. The plow is then slowly pulled over the cars and the ballast forced off. The plow is the same width as the inside of the cars, and is guided by either a ridge along the centre of the car or by the posts supporting the side doors. In the case of centre drop cars the doors are opened and the train slowly passes over the track. By this means the ballast is evenly distributed.

The cost of ballast in the track varies with the different roads. It depends on (1) first cost of material, as it comes to the road; (2) on the distance of the source of supply to the place where it is used and on the method of handling. The first cost of cinders or slag is frequently insignificant, a gravel pit may cost nothing except the price of a little additional land beyond the limits of the right of way. Stone will usually cost $1 or more per yard. The cost of handling per cubic yard will be small if a steam shovel is used, but hand shovelling will cost more. The cost of hauling depends on the distance hauled and also on the amount of traffic, for the work train must keep out of the way of the regular trains. The cost of broken stone ballast in the track is estimated at $1.25 per cub. yard, and gravel at about 45c. to 50c. per cubic yard.

The amount of ballast needed per mile is:

Single track, stone, 2,300 cub. yards; gravel, 1,900 cub. yards.
Double track, stone, 5,300 cub. yards; gravel, 4,100 cub. yards.

Thus the difference in cost between gravel and stone per mile of single track is $2,020, and per mile of double track, $4,780.

TIES.

In order that the rails may have a firm foundation to rest on, and also be held rigidly at a certain distance apart, some form of tie is necessary. There are many different forms of supports and ties, but the one familiar to us is the wooden tie.

The essentials for a good railroad tie are few compared to the essentials in wood for other purposes. These essentials are mainly durability, resistance to the cutting action of the rail, and ability to hold the spike firmly. All woods do not fulfil these requirements, as some are hard and some soft, so they differ in the main essentials of a good tie. There are many varieties that are found satisfactory, such as white and red oak, yellow pine, white and red cedar, beech, maple, spruce, hemlock and tamarack. The commonest kinds in use to-day are red and white oak and cedar. Cedar is common in Canada, but the oak ties are almost all imported.

The oak tie is mainly used on curves, and the cedar on tangents. The reason for this is that the outward thrust of the rail would soon loosen the spikes in a softer tie. It is also the best wood for ties, both for wear and durability combined, being very hard and slow to rot, and generally failing by decay rather than by wear. The cedar ties are good and durable, but their softness leads to cutting under the rails.

The life of a tie depends on its resistance to natural decay and its ability to resist the cutting and abrading action of the rail. On a main line the average life of a cedar tie is 7 to 8 years, while on a branch line the same tie will last 12 to 15 years. Red oak has a little longer life than cedar under the same conditions.

Almost every railroad has its standard size of ties, but the majority favor a tie 8′ or 8′ 6″ long, 6″ to 7″ thick, and 8″ to 9″ wide. For heavy traffic the length of the tie is sometimes 9′.

The spacing of ties varies from 14 to 18 per 30′ rail, depending on whether it is a main line, branch line or yard track.

In the maintenance of way account the cost of ties is quite an item, as thousands are required for renewals, and the price per tie is about 41c. for cedar and 58c. for creosoted oak.

Because of the rather short life of a tie in the track many preservative processes have been tried, and several of them add considerably to the life of the tie.

The different processes are creosoting, zinc chloride, zinc tannin and Wellhouse. In the creosoting process the ties are first placed in a large iron cylinder and the air exhausted, thus drawing out the sap. Live steam is then turned in for about 20 minutes, when it is shut off and a vacuum again created to open the pores of the wood. This lasts about 20 minutes and live steam is again turned in, the pressure raised to 30 lbs. per square inch, and maintained six to eight hours. The steam is then blown off and a vacuum created, after which hot creosote oil is run in, the pressure raised to from 80 to 100 lbs. per square inch, and maintained from one to two hours, depending on the size and kind of the timber.

The oil most commonly used is dead oil of coal tar. It is obtained by the distillation of coal tar, and its preservative value lies in the fact that it contains napthaline, which melts about 175° F., so that after being liquified by the heat of the steam it penetrates the tie, becomes solidified and is permanently fixed. The ties subjected to the process should be well seasoned and dry, as then they will take up a great deal more of the oil which, when solidified by exposure, no moisture in the air or ground can succeed in removing.

The mechanical part of the other processes is much the same, but as their names indicate a different preservative is used. In each process a vacuum is first obtained, and then in the zinc chloride treatment zinc chloride is forced into the ties. With the zinc tannin process first zinc chloride, then a weak solution of tannic acid, and after that a 1% solution of glue is injected. The Wellhouse process is the same as the zinc tannin, but the zinc chloride and glue are mixed together and injected at the same time, while the tannic acid is injected a short time afterwards.

The preservative processes have been given a great deal of attention during the last few years, as the forests are rapidly becoming depleted and suitable wood is becoming scarcer every day, so that what wood is now available should be made to last as long as possible.

RAILS.

The development of the modern rail may be briefly summarized as follows: Flat cast-iron rails or plates, about three feet long, were first used, and these were succeeded by cast-iron rails of L section, laid with the horizontal flange outward, the ends of the rails resting on stone blocks. On these angle rail tracks flangeless wheels were used. About 1789 edge rails were introduced, the wheel running on the upper edge of the rail and being guided by a flang on the wheel. The first were of cast-iron, fish bellied, in short lengths of about 3′, with the ends resting on stone blocks, or in cast-iron chairs on these blocks. Later on the rails were made of wrought iron in 15′ to 18′ lengths, fish bellied, between supports about 3′ apart. These rails were rolled, the rail and rolls being invented by John Birkinshaw, of England, in 1820. The bridge rail, designed in 1834, was used on some of the early railways. The pear section was an approach to the present form, but was very defective on account of the difficulty of designing a good form of joint.

The present flange, or T rail section was invented in 1830 by Colonel Robert L. Stevens, Chief Engineer of the Camden and Amboy Railway, and the first order was placed in England by him for this road. Various forms of compound rails have been designed, particularly in the early days of railways, to enable the wearing part of the rail to be renewed, but the majority proved failures, owing either to faulty connections or too great complications. The idea has, however, been revived in connection with modern heavy track, and in 1894 the compound rail, shown in the figure, was suggested.

Up to fifteen years ago there was an almost entire lack of uni-

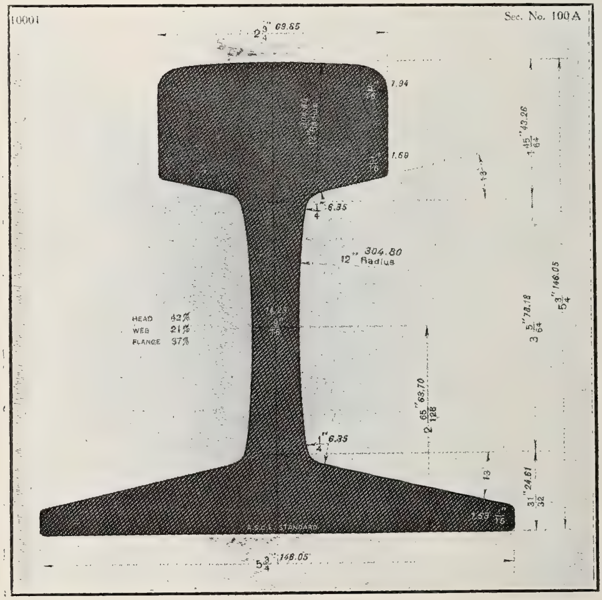


Fig. 1. A.S.C.E. Standard 100-Pound Rail

formity in rail design, and the mills had to carry enormous stocks of rolls for the innumerable forms of section. Many of these sections were practically identical, but had minute variations in certain dimensions, as the result of the whim of the designer, or his being unaware of the existence of a practically similar section. Each engineer had his own ideas as to rail design, and desired to have his own special form of section on his own line.

In 1893 the American Society of Civil Engineers, after a very thorough investigation extending over a number of years, having obtained the opinions of the best experts of the country, adopted a series of sections, which have been used by American and Canadian railways.

Instead of having the rail sections for various weights to be geometrically, similar figures, certain dimensions are made constant regardless of the weight. It was decided that the metal should be distributed through the section in the proportions of head 42%, web 21%, and flange 37%. The top of the head should have a radius of 12″, the top corner radius should be 5-16″, the lower corner radius of head should be 1-16″, the corners of the flanges 1-16″ radius, side radius of web 12″, top and bottom radius of web corners ¼″, and the angles with the horizontal of the under side of the head and the top of the flange 13°.

The sides of the head are vertical. The height of the rail and the width of the base are always made equal to each other.

A standard composition of rails of 90 lbs. per yard and upwards is carbon .5 to .6.

Phosphorus, not over....................	.1
Silicon, not over......................	.2
Manganese	.8 to 1.10

The standard lengths are 30 and 33 feet, but 10% of the order must be accepted in short lengths varying by even feet down to 24′. Also a variation of ¼″ from the length specified is allowed.

Rails break far more frequently in some places than in others and the commonest place is in the head where they split parallel with the length of the rail. Then the head may crack across, the crack will extend down to the top of the web and then run back along the web so that perhaps 4′ or 5′, or the whole head may come off. Then again the side of the head may break off.

These breaks occurring very frequently in the head and the under side of the head naturally lead us to look there for the defect. Such breakages were not common in the old Barrow rails and this may be accounted for by the fact that the radius of the fillet between the web and the head was greater in the Barrow than in the modern rail.

Rails are liable to break on straight track as well as on curves and at all times of the year, but there is a greater number of failures in the spring, when the frost is coming out than at any other time of the year. In some cases the rail breaks straight off or nearly so. These breaks occur both on the ties and between the ties and are probably due to the heavy blow of a flat wheel striking a weak spot on the rail.

The minimum weight economical in ordinary service is 65 lbs., though many roads have used lighter rails even under considerable traffic. In such cases, however, the diminished life of the ties and rails and the increased cost of material and labor for maintenance and renewals as well as the occasional sums involved in repairs and damage suits after wrecks, more than balance the cost of rails of suitable weight.

For ordinary freight and passenger traffic on roads with easy curves and grades the weight should be 70 to 80 lbs., while for extra heavy freight or fast passenger trains or on lines with sharp curves and steep grades the rails should weigh from 80 lbs. upward.

To illustrate how heavy rails and stiffness assist the tractive force of engines the experiment of hauling a train load of 378 tons at a speed of 55 miles per hour over 65 and 80-lb. rails showed that it took 820 horse power on the 65-lb. rails and 720 horse power on the 80-lb., while it was estimated 620 h.p. would have been required on 105-lb. rails.

The cost of rails to-day is about $30.50 and 18 cents inspection, making a total of $30.68 per ton. At that price one mile of 100-lb. rails would cost $4,821.

SUPERELEVATION.

As a rule the outer rail on main line curves is elevated a certain distance above the inner rail. The elevation depends on the degree of the curve, on the speed at which trains pass around it and the relation of the curve to the grades on either side of it.

A common practice is to elevate ½″ to 1¼″ per degree. The reason for such a range of elevations is apparent when we consider a double track road on, say, a 0.5% grade. The elevation of the curve of the ascending track should not be as much as the descending track and in case of a curve upon the summit the amount of elevation should be less than that of the same degree of curvature on a comparatively level track. Again a curve at the foot of a grade should have more elevation than the same degree of curve with no grades near it. This, of course, simply means that the curve must be elevated with regard to the speed of the trains and also with respect to the radius.

Satisfactory and easy as this may appear to be, it becomes a very complicated problem in the case of a single track road having a continual rise in one direction. Then there are four widely different speeds to consider. The speed of freight and passenger trains going in the direction of the rise and the same trains going in the opposite direction.

It is evidently impossible to elevate a curve to suit all four speeds and the practical way it is done is to elevate 1⅛″ for each degree of curvature, the elevation never to exceed 7″ and then closely watch the track to see the effect. *The manner in which the rails wear and act is the surest indication of having a practically* *correct elevation.* If the low rail wears badly and tends to spread the elevation is too great, while if the high or outside rail becomes worn and shoved out of place the elevation is insufficient. It is then left to the track foreman to find by experiment the elevation at which both rails wear evenly and there is no evidence that one rail tends to spread more than the other.

SWITCHES AND FROGS.

In order that a train may pass from one track to another a switch is necessary. The first switches used were called stub switches, but as they were the cause of many derailments and are not suitable for main line the railroads have adopted the split or point switch. This switch consists essentially of two point rails by one of which the flanges of the wheels are diverted on to the turnout or switch and a contrivance called a frog having channels on its upper surface through which the flanges of the wheels pass.

The parts of switch that have to withstand the greatest amount of wear are the points and the frog. In the case of the points the wear is caused by the pressure of the wheel flange and this tends to squeeze the metal and distort the point. A hard blow will somtimes break off a piece of the point rail.

For these reasons manganese steel points are coming into favor for switches that are constantly in use on main line or yard tracks where the volume of traffic wears out Bessemer steel points in a few months. Because of their cost manganese points are not economical except under conditions where by their toughness and great wearing qualities they outlast many pairs of ordinary steel points.

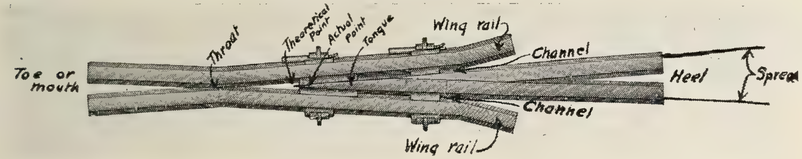


Fig. 2

Frogs are classified according to the spread of the rails composing the frog. A spread of one foot in eight feet is called a No. 8 frog, similarly a spread of one foot in twenty feet is called a No. 20 frog. The common numbers in use run from 4 or 5 for a very sharp turnout to a 12, 14 or 20 for a main line junction.

Frogs were originally made of cast iron but the present universal practice is to build the frog up of pieces of rails which are cut and bent as required. These pieces of rail (usually four) are sometimes assembled by rivetting to a flat plate but this method is now but little used. The present practice is now chiefly divided between bolted and keyed frogs. In each case the space between the rails except a sufficient flangeway is filled with a cast iron filler and the whole assemblage of parts is suitably bolted or clamped together.

The distance from the point of the frog to the point of the switch or the lead, as it is called, depends on the number of the frog. The theoretical lead (the formula for which is twice the gauge multiplied by the number of the frog is never used as it does not give an even curve on the turnout is very hard to line accurately, and in the case of a long lead all the curve will be found on the first rail or two following the switch point. For those reasons the shortened or practical lead is used. This lead may be calculated as follows for No. 6, 7 or 8 frogs nine times the number of the frog gives the shortened lead in feet, for 9 and 10 frogs eight and a half times the number of the frog and for frogs above 10, eight times the number of the frog. For example, a No. 9 shortened lead should be $9 \times 8\frac{1}{2} = 76\frac{1}{2}$ feet, but in order to save cutting rails even this lead may be varied several feet.

The two kinds of frogs in use are rigid and spring rail. The rigid frog is provided with two channel ways or flange spaces through which the flanges of the wheels pass. Since the wheel tread is always wider than the rail, the wing rails will support the wheel not only across the space cut out by the channels, but also until the tread has passed the point of the frog and can obtain a broad area of contact on the tongue of the frog. This is the theoretical idea, but it is very imperfectly realized. The wing rails are sometimes subjected to excessive wear owing to the hollow or worn treads of wheels.

The break that the channels make in the continuity of the rail becomes extremely objectionable at high speeds, being mutually destructive to the rolling stock and the frog. This led to the introduction of a frog having one wing rail operated by a strong spring so that the wing rail is held close up to the tongue and thus gives a practically continuous rail for the main track. The spring rail only comes into operation when a car goes on the siding and when this happens the flange of the wheel presses back the spring rail thus making the necessary channel. The Eureka spring rail frog has given satisfaction wherever used.

Manganese steel frogs first came into use in 1901 and since that year they have come to take a place of their own in track work. They are most economical for terminals where the constant passing of trains soon renders a Bessemer steel frog useless, but because of their high first cost they are only used in places where an ordinary frog lasts but a few months.

In these days of many railroads crossings of one road by another are frequent. A diamond is put in at the crossing. This is usually built up of parts of rails, but with modern high-speed and heavy trains a rail diamond, no matter how well it is reinforced, must be constantly looked after and repaired. If the tracks are in constant use a Bessemer steel diamond is soon hammered out of shape by the pounding it receives. For this reason manganese steel castings are being used for the wearing parts of diamonds. This metal is so very tough and hard that a file or chisel will not make a mark on it and in order to smooth it off at all it must be ground. It is practically indestructible and will last a very long time without showing any signs of wear beyond a very white polished surface.

ACTION OF THE ROADBED.

One of the many things to be considered in constructing a railroad is the drainage, as it frequently causes a large outlay after the road is in operation. Where the road is on an embankment the drainage problem does not present itself but if a long deep cut is introduced then the engineer must carefully look after the side ditches and see that they are made of sufficient size and depth to carry off all water and properly drain the track.

Each railroad has its standard width of roadbed and side ditches but as the material through which the cut is run is very frequently clay they are almost certain to have a wet spongy track unless carefulness is exercised both in constructing the side ditches and in placing sufficient ballast under the ties. It has been observed that in a cut where the roadbed is of clay and where perhaps there are only 10 to 12 inches of ballast between the under surface of the tie and the top of the roadbed a swelling of the clay will occur between the ties.

This is caused by there not being sufficient ballast under the tie to distribute the weight on the tie evenly on the roadbed. As a result the ties press nearly directly on the soft wet clay and thrusting down into it cause it to swell up in a ridge between them. The distortion of the roadbed is frequently noticeable, as the clay also squeezes out laterally and partially fills the side ditches.

In the case of a freight yard constructed a few years ago insufficient ballast was allowed, the drainage was rather poor, and to-day the yard foreman spends the greater portion of his time watching his men jacking the ties up out of the mud and putting cinders under them.

Thus a wet, spongy, unsatisfactory track that is costly to maintain is the direct result of being economical of ballast and careless of drainage.

In 1890, after three years of experimenting it was found that a swelling of the clay between the ties will not occur even under the most favorable conditions when the height of the under surface of the tie above the roadbed is eight inches more than the clear distance between the ties. This shows that in any locality where the surrounding conditions indicate that a wet track is to be expected, a liberal supply of ballast should be placed under the ties.

However, practical experience shows these experiments were in error as the above procedure does not always result satisfactory. The track is still saturated with water and until this is drained away the ballast will sink down into the clay and the clay will ooze up.

The only remedy that gives lasting satisfactory results is to thoroughly drain the cut with tile drains placed in the ditches.

TIE PLATES

One of the most important and practical of modern improvements in railway track has been effected by the wide introduction of metal tie plates which are placed between the rail and the tie and which involve only a small first cost but effect a most decided economy in ties and in track work. Their cheapness combined with their undoubted advantages in efficiency and economy has led to their adoption on hundreds of miles of track as it is recognized that they not only increase the life of soft and cheap, though durable, untreated ties but effect a direct economy in renewals and maintenance of way; while at the same time they add to the permanence and security of the track by giving a uniform and durable bearing to the rails and lessening the disturbance of the track for tie renewals. They are especially advantageous for soft ties under heavy traffic. The life of a soft-wood tie is very much reduced by rail cutting and by not offering sufficient resistance to the moving of the spike thus causing rot around the spike holes and frequently requiring renewal before decay has set in.

Tie plates cause the spikes on both sides of the rail to act equally to resist lateral pressure in either direction as the plate ties the two spikes together. The spikes clasp the base of the rail tightly, thus preventing it moving and so reduce the wear or necking of the spikes by the rail.

It is a very important feature that the spike holes should be so punched that the spikes will fit closely to the base of the rail. Otherwise a lateral motion of the rail will be permitted which will defeat one of the main objects of the use of the plate. A standard distance between the holes is 1-16″ less than the width of the rail base.

It has been practically demonstrated that the rail cutting is not due to the mere pressure of the rail on the tie even with a maximum load on the rail but is due to the impact resulting from vibration and to the longtitudinal working of the rail. It has been proved that this rail cutting is practically prevented by the use of tie plates.

On steep grades they prevent the increased cutting of the ties due to sand from the engines getting under the rail and abrading the wood. Tie plates also act as effective rail braces for the outside rail of curves.

The cost of tie plates is very small compared with the value of the added life of the tie, the large reduction in the work of track maintenance and the smoother running on the better track which is obtained. It has been estimated that by the use of tie plates the life of hardwood ties is increased from one to three years and the life of softwood ties is increased three to six years. From the very nature of the case the value of tie plates is greater when they are used to protect soft ties.

Tie plates may be used with special advantage as follows: In terminal yards, on bridges, on sharp curves, on the ties in the switch lead, at rail joints on tangents and on a busy main line where the heavy traffic causes the ties to be cut into by the rails before decay sets in.

Many forms of tie plates have been introduced. The first plates used were flat pieces of boiler iron with holes punched for spikes. The next was a flat-bottomed plate with a shoulder on top. Both of these had many disadvantages. It was impossible to keep them tight, hence they caused wear and decay and also jumped and rattled under passing trains.

Besides the plates tended to bend and buckle, while if made sufficiently thick to resist bending, the plate was clumsy and expensive. The question then was how to secure a permanent connection between the plate and the tie and this appears to have been efficiently attained by making a plate with longtitudinal ribs or flanges which sink into the fibres of the weed from ¾″ to 1⅜″ and are tightly held by them while the size of the flanges is not such as to crush or split the wood. These flanges also serve to stiffen the plate and enable a thin plate to be used without bucking under heavy loads. The plate with longitudinal flanges has proved by length of service that it has a secure grip on the tie and protects the wood, while the objection that it causes the tie to split and thus hasten decay has not been sustained.

It is claimed that the tie plate with four spurs projecting into the tie across the grain has a grip equal to that of four good spikes and that the spurs require a constantly increasing lateral load to move even when once started. This, of course, means that when once seated the plate is absolutely fixed but the same may be said of the longitudinal flange plate.

The best forms of tie plates are of comparatively recent design and experience with them is still insufficient to determine beyond all question which design is best.

A very important detail in the process of setting the tie plates on the ties is that the flanges or teeth should penetrate the tie as far as desired when the plates are first put in position. It requires considerable force to press the teeth into the tie. In some cases trackmen have depended on the easy process of waiting for passing trains to force the teeth down. Until the teeth are down the spikes cannot be driven home and this apparently cheap and easy way results in loose spikes and rails. If the trackmen neglect even temporarily to tighten these spikes it will be impossible to make them tight ultimately.

The plates are generally pounded into place with a 10-16 pound sledge hammer. A very good method was adopted once when a pile driver was at hand. The bridge ties with the tie plates accurately set to gauge on them were placed under the hammer and the plate forced home by a 2′ or 3′ fall of the hammer.

One of the first questions that you may have in mind is "Why is the width of the track between rail heads or the gauge, as it is called, 4′ 8½″? Why not 4′, 5′ or 6′?"

It is not known what, if any, principle governed the determination in the first instance of the distance between the rails of 4′ 8½″. It was adopted by the roads from the colleries in the north of England and believed to have arisen from the colliery wagons in use on common roads, having an outside width of axle of 5′, for, as the tramroads had the flange on the outer edge of the rail these ordinary wagons could be used on them and when the flange rail was replaced by the edge rail the same width of track was continued but measured from the inner edge of the rail resulted in the 4′ 8½″ gauge. Another reason given by an authority is that the tramways were 5′ wide, including the rails, and as the later edge rails were 1¾″ wide they practically determined the gauge at 4′ 8½″ as soon as they were introduced. Mr. Stephenson engaged in these colleries, was selected to build the Liverpool and Manchester road, and seeing no reason to change the gauge with which he was familiar, it was adopted there. As that gauge proved satisfactory on the Liverpool and Manchester it was used by some other roads as they were built. The necessity of having a standard gauge no doubt arose out of the fact that with any other gauge the interchange of loaded cars was an impossibility. As traffic increased and one road having a certain gauge received freight to be delivered on another road having a different one it was evident that a common gauge was necessary. However, the majority of railroad companies had a gauge of 4′ 8½″ and as they were unwilling to change it, 4′ 8½″ was decided on as the standard.

NOTES ON THE CAUSE AND PREVENTION OF THE CORROSION OF IRON

F. N. SPELLER, B.A. Sc.

The corrosion of iron has been the object of investigation and experiment for many years, but not until recently has the subject been dealt with on broad scientific lines with the object of determining the underlying causes and scientific methods for prevention of corrosion. The need of careful practical research along this line is evident when we consider the interests at stake and the increasing destructive nature of modern corrosive agencies.

Theories of Corrosion.—To explain the underlying causes of corrosion, any theory must account for the fact that iron will remain bright indefinitely in water free from air, and is equally well preserved in air free from moisture. Commercial wrought iron and steel are here considered together as "iron," a clear distinction being in fact difficult to make.

For many years the carbonic acid theory was considered satisfactory. Two reactions are said to occur. In the first carbonic acid is an essential agency.

$$(1)\quad 4Fe + 4H_2O + 4CO_2 = 4FeCO_3 + 4H_2$$

$$(2)\quad 4FeCO_3 + 6H_2O + O_2 = 2Fe_2(OH)_6 + 4CO_2$$

There seems to be good ground for the belief that the presence of CO_2 in solution accelerates corrosion considerably. However, while not overlooking the effect of CO_2 (which requires further investigation), it was conclusively shown by Whitney in 1903 and quite recently confirmed by A. S. Cushman and W. H. Walker and others, that iron will go into solution in water entirely free from carbonic acid. The latter investigators, on the suggestion of Dr. Cushman have worked out a method for showing the solution of iron by means of a combination of two delicate indicators (called Ferroxyl by Dr. Cushman). If we add a few drops of phenolphthalein to distilled water, render neutral, with 1/100 normal caustic soda, and then run in enough of a fresh solution of ferricyanide of potassium to turn the water faintly yellow; on dropping in a piece of bright iron, blue areas will appear after a few minutes where ions of iron are entering the solution at the positive pole, while pink areas due to the presence of hydroxyl indicate the negative pole where hydrogen ions are leaving the solution, thus showing, as claimed by Whitney, that the initial corrosion of iron is an electro chemical phenomena.

The reaction is analogous to what happens when we immerse a piece of iron in sulphate of copper, hydrogen occupying a position between iron and copper in the electrochemical series. The solution pressure of the iron will force some of the metal into solution, a

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* **Metallurgical Engineer, National Tube Co., Pittsburg.**

proportional amount of copper being plated out on the surface of the iron. In the corrosion of iron, hydrogen is plated out at the cathode, the hydroxyl liberated being indicated by the pink coloration with phenolphthalein. In experiments which we have made on solution of iron in air free water, it was found that after the concentration of iron in solution reaches a certain small amount (about 1 part in 5 or 10 million) the reaction practically ceases, due to polarization at the cathode, and by virtue of the back pressure of the iron already in solution as ferrous hydrate.* A secondary action now takes place in corrosion if a small amount of oxygen is present, whereby, as Prof. Walker has experimentally proven, the cathode is depolarized. The ferrous hydroxide is at the same time changed to ferric hydroxide, which is thrown out of solution as "rust." In this way the electrolytic theory accounts for the phenomenon we are all familiar with in every day life.

Now let us go back to the ferroxyl tests and learn, if possible, the origin of this difference of potential. It was at first assumed that the blue and pink areas indicated irregularities or lack of homogeneity in the metal itself. In order to ascertain the value of this polarity indicator as a means of detecting irregular distribution of the constituents in commercial iron, polished sections of plates were examined,the centre of the sample being from the central segregated portion of the ingot and the surface portion corresponding to the outer skin of the ingot, giving a comparatively wide difference in composition between spots on the same section less than 1/4″ apart when the sample is taken from the most segregated portion of the ingot. The sides of these samples were carefully covered with cotton soaked in shellac, which was allowed to harden to prevent scale or oxide from influencing the results, as a number of trials without this precaution showed the oxidized sides to be invariable cathode to the clean surface of the section. With this precaution it was found impossible to get the same configuration of the surface under ferroxyl twice, and no consistent effect was manifested between the segregated and purer portions adjoining, except in a few cases, where there was excessive segregation, the central portion then showed a tendency to go into solution, while the outside portion became cathodic. The polarity, as indicated in pink at the cathode and blue at the anode, gradually changes and reverses itself curiously, causing corrosion to progress uniformly, provided no influence is present to hold the polarity in one direction continuously. Here we have a probable explanation of pitting.

In 1904 the writer made an extensive investigation of the influence of oxidation of the surface on the polarity of two pieces of steel, and was struck by the large difference in potential (as much as 2/10 or 3/10 of a volt) found between clean iron and mill-scale. Ordinary rust or other substances electro negative to iron adhering to the surface will produce the same effect to a lesser degree. Take two clean iron rods connected by copper wires to the calibrating coil of an ordinary volt meter and immerse in salt water, a slight difference in potential will usually be shown. Now without disconnecting the wires, take one of these rods out into the air for a few seconds and replace it—a strong deflection amounting to, perhaps, 50 milli volts will be indicated with the electrode which was aerated as cathode. By replacing this rod and removing the other from solution for an equal length of time or perhaps a few seconds longer and replacing in the water again the current will be found to have reversed. With such controlling differences in potential, due to accidental irregularities in oxidation of the surface of iron and steel, the slight variation caused by such lack of homogeneity in composition as may occur on the surface of the average steel or iron plate, probably plays a minor part. This is not said to excuse poor work, for there is no doubt that carelessly made iron or steel shows up badly under corrosion, but many good pieces have pitted through for other causes than irregular composition, and according to our experience this is more often the case. When we were going through the laboratory stages of experimental work on corrosion, in one case pieces of the same tubes were immersed in aerated water, one being cleaned free from scale and the other in its natural state. The latter pitted badly, while the clean sample corroded uniformly.

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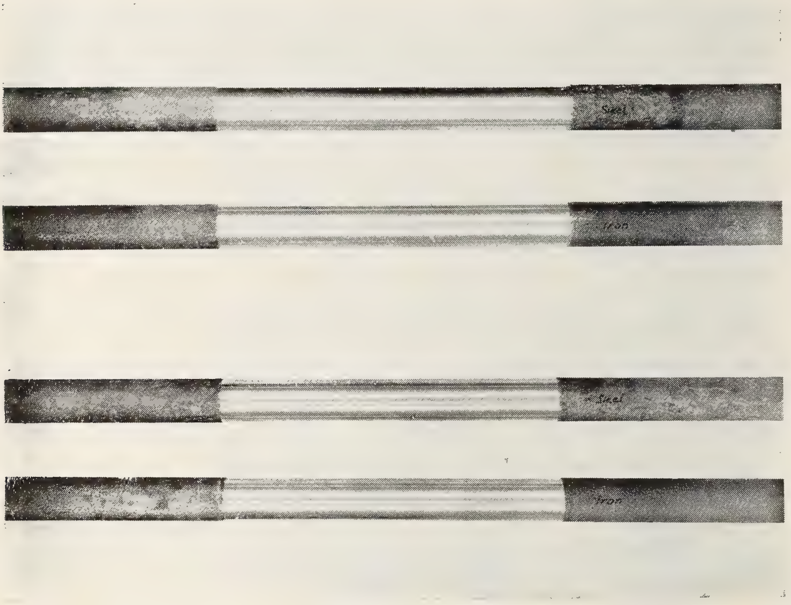
* We have measured the effect of ferrous sulphate in solution in the pickle baths used in the galvanizing works and found 40 per cent. ferrous sulphate to reduce the rate of solution of iron 100 per cent. in solutions where the free acid was maintained constant at 4, 5 or 6 per cent.

The rate of corrosion evidently depends more on the oxygen available than on any other factor, and whether the corrosion proceeds uniformly or is concentrated in pits, seems to depend more on the irregular distribution of foreign impurities in contact with the surface rather than on segregated spots of manganese or other elements which we find combined with steel. In some cases irregular density or flaws may contribute to localize corrosion; this will be referred to under a later head.

Does Wrought Iron or Steel Offer the Greater Resistance to Corrosion.—There is not space to discuss this phase of the subject in detail, but we can testify that so far as pipe and tube steel is concerned (and our investigations have been along this line entirely) the general impression which has prevailed as to the superior rust-resisting quality of wrought iron seems to be far astray from the truth. Theoretically there is no valid reason to expect one material to last longer than the other, and many laboratory tests show no material difference. Service tests of pipe and tubes, which have been conducted with special care as to equality of conditions, sustain this conclusion. For example, records of tests started nearly two years ago on a dozen railroads, at different parts of the country, show welded steel tubes to be equal and even superior to charcoal iron. It should be understood that this tube is made of soft steel which receives special attention as to uniformity and manipulation, it having been found that thorough working of the steel, while at the proper temperature, has much to do with its life. The conditions in a mill making pipe and tube steel exclusively are ideal so far as uniformity is concerned, in fact a high standard of material must be maintained if a satisfactory percentage of the steel made is to pass successfully through the ordeal at the welding furnaces.

Some have thought that the higher manganese would lessen the resisting power of steel compared with iron. When thoroughly mixed by a proper ladle reaction there can surely be no reason to suppose that a moderate manganese content is harmful; the ferroxyl test (the most delicate devised) does not show that steel carrying .30% manganese is affected perceptibly different from that made with .10% manganese. As to the uniformity obtainable in steel, we recently made a test by taking a sample from the last of the steel out of the ladle. Comparing the analysis of this with the regular ladle test: the maximum difference in manganese in 150 heats was found to be .05%, but in the majority of cases amounted to only .01 or .02%.

One example of a number of corrosion tests now under way might be cited. The question of relative durability of iron and steel condenser pipe having come up, we arranged 20 lengths of 2″ pipe alternately iron and steel in two racks and kept water dropping over them continuously in a warm place. The attached photograph shows the condition of four of these pipes, iron and steel, after 15 months, the centre portion having been turned down in a lathe below the deepest pit. No difference could be seen at this time. Many more tests under special conditions of service might be cited, but it is more satisfactory where the consumer is sufficiently interested to test the matter out under the conditions as you have them, bearing in mind that apparently slight changes in environment will greatly



Comparative Corrosion of Steel and Iron (Upper Steel) alter the results, hence the samples should be carefully placed so as to insure equality of conditions.

Results of a service test, conducted by Mr. T. N. Thomson, Sanitary Engineer at the International Correspondence Schools, Scranton, Pa. (American Society of Heating and Ventilating Engineers Annual Meeting, January 19th, 1908), show, in a hot water pipe line, consisting of alternate pieces of iron and steel that the steel corroded more uniformly and had decidedly the longer life. This investigator also throws some light on the cause for some of the aforementioned feeling which has caused many to continue to specify wrought iron when soft steel could be used to better advantage. It was found in the course of investigation among engineers, contractors, architects and steam fitters, that many were unable to distinguish between iron and steel, the presumption being that if the metal stood up well it was the traditional wrought iron, but if, on the other hand, it pitted badly no investigation was necessary, it being safe to conclude that the pipe was steel. This prejudice, or lack of knowledge of the materials and properties of welded pipe, is now less commonly met with.

PROTECTION FROM CORROSION.—The obligations of the iron or steel manufacturer are to produce a metal as homogeneous in composition as possible with a uniformly close texture developed to the best that is in it by proper treatment according to requirements. Such a metal will, of course, still rust, but with a greater uniformity than one made only with regard for the shape it is to take. Taking the electrolytic theory as our guide, there are evidently two general methods of protection, viz., making the iron insoluble, or as the electro-chemist might say, preventing the hydrogen from plating out of solution, or by protecting the surface from oxygen.

Iron in the passive state will not go into solution. This state is brought about by various agencies, for example, the action of concentrated nitric acid or chromic acid, an electric current with the piece to be passified as anode, or by chromates, ferricyanide of potassium, and other salts; potassium bichromate is probably the cheapest of these, a piece of bright iron immersed in a concentrated solution of this salt for several hours and then well washed in water will not corrode in moist air or water for some time. The protection is, however, not permanent, and is destroyed by heating to the boiling point of water.

NOTE—Passivity is explained by Dr. Cushman as due to retention of oxygen on the surface of the metal; other investigators believe that electric currents have much to do with it. The phenomena can be produced by an electric current, and the iron actified again by passing a current in the reverse direction with the passive iron as cathode. Is it not possible that the negative areas on the surface of a bright piece of iron which give a pink coloration with ferroxyl are due to passivity of the metal at these points brought about perhaps by different concentrations of oxygen on the surface of the metals?

We have frequently noted that where the polarity was changing under ferroxyl, the anodic areas were not strictly bright but appeared as though a film of oxide was forming on the surface, gradually making the anode less positive and finally reversing the direction of the current.

We can easily see how the reversal of polarity is accelerated if we assume that the cathodic areas are originally slightly passive, for they will soon be actified in contact with positive or active iron according to experiment by H. L. Heathcote.

(Soc. of Chem. Ind. Aug. 31, 1907.)

By immersing iron in a weak solution of bichromate of potassium (1 lb. in 1,500 gals. of pure water), Dr. Cushman has observed that the metal remains bright indefinitely. In order to determine whether the protecting influence could be relied upon at higher temperatures, we have kept weighed pieces of bright iron in a solution of 1 part to 1,500 of distilled water for four months at 95 degrees in a flask open to the air, but loosely covered with a simple condensing apparatus. At the end of this time the pieces were apparently unaffected, and curiously in every case, increased in weight slightly. It would seem that this treatment of the water might give good results in certain cases, for example, in boilers or steam-heating plants.

The treatment of water with alkalies also comes under this class of protection, the iron being prevented from going into solution in virtue of the concentration of hydroxyl ions.

Under the second method of protection we may class protective coatings, such as the various paints and oils, or where the iron is submerged we may remove oxygen and other corrosive matter from the water which comes in contact with the exposed surface.

In discussing the latest conception of the process of corrosion we have distinguished between two distinct operations, firstly, in solution of a very small quantity of iron, so slight as to be of no practical concern in itself, especially as the reaction soon comes to a stop unless oxygen is available, in which case we have a secondary reaction by which continuous corrosion is made possible.

For the protection of boilers, the air may be removed by heating the water in a vessel open to the atmosphere, as in the case of one class of feed water heaters, whereby the greater portion is driven out; corrosive gases left in the water after treating, can be removed by contact with a large surface of clean iron turnings or borings. A small amount of iron goes into solution, and the ferrous hydroxide thus formed takes up oxygen from the water, thus the boiler is protected at the expense of waste iron, which can be cheaply renewed from time to time as required. It is a common experience to find the portion of a boiler or heater nearest to the feed water entrance corroded while the rest of the boiler is unattacked. The same thing is seen in hot water heating systems, which very rarely, if ever, give trouble through corrosion, so long as the same water is used over and over in the system, but if hot water is drawn from the pipes for washing or other use and cold water fed in, corrosion ensues, the life of the system depending on the amount of cold water put in. Under these latter conditions it has been shown that standard 2″ iron or steel ppie may not last much over two years. We have found that by passing heated water through a bed of iron trimmings about 18″ deep, in which weighed samples of steel plate were placed at the top and bottom, that the top samples pitted badly and lost about five times more in weigh than those pieces at the bottom.

This has been a mere outline of the principles of corrosion, as we understand them at present, in an attempt to show their practical application. The subject is being energetically investigated, and further development may be expected in the near future.

A PRACTICAL SYSTEM OF REINFORCING CONCRETE

*H. F. PORTER, C.E.

When I was asked to address this meeting I did not expect to have the honor of taking sides, as it were, in a debate on the subject of reinforcing systems. As it happens the preceding speaker has exploited to you the merits of one distinct type, which involves the use of rigidly attached diagonal stirrups to the main reinforcing member. The system which I shall endeavor to explain is based entirely upon the use of plain bars, which can always be obtained readily and at the lowest price per pound. Working along this line, we have endeavored to develop a logical, practical, and economical system of reinforcement that would meet at the same time, in so far as possible, all theoretical and practical demands of an ideal system. How far we have succeeded, I shall leave you to judge. In any event, in the large number of installations in which this system has been used, we have enjoyed unusual success, not alone in keeping down the costs, but in making possible rapid construction, accuracy of work and the realization of a large factor of safety. The exponents of a leading American system of patent bar reinforcement, I refer to the Kahn bar—claim to have developed factors of safety of ten and eleven, whereas the building laws have required only a foctor of safety of four. With this system of plain bar reinforcement, which I shall try to explain to you, factors of safety as large as thirteen have been attained, and in every case where failure has resulted, it has been by pulling in two of the horizontal reinforcement and not by failure of the concrete in diagonal tension or compression. Evidently, then, as this is the ideal method of failure, we have in this system provided properly for all of the stresses.

The preceding speaker has explained to you the theory upon which the system of reinforcement using rigidly attached diagonal members is based; and for freely supported rectangular reinforced concrete beams there is no gainsaying that this is a proper and also an economical method. However, in practice, beams of this character are rarely encountered. Instead the ma-

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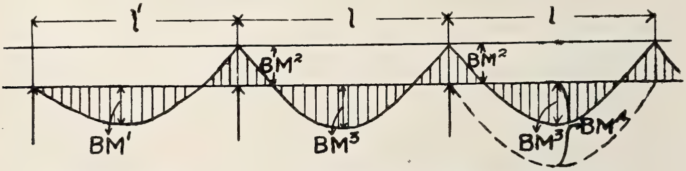
jority of beams will be continuous over several supports and being monolithic with the floor slab, will act in every case as T-beams. There is one exception—the end span—in which at the best only partial fixity of construction can be secured; but, by properly adjusting the length of spans, this weakness of the end spans may be compensated for, allowing the use of the same reinforcement throughout. If the end span cannot be made shorter than the intermediate spans, then it will be necessary to provide for the loss of strength by increasing the amount of steel. For practical purposes it is advisable to preserve uniformity in the amount and kind of reinforcement, so that the former method is preferable.

The subject of continuity is one that engrosses the entire engineering world to-day. There is no question whatsoever that concrete, in view of its monolithic character, must develop continuity of action, and it seems, therefore, logical to work on this basis in developing a satisfactory method of reinforcement. True, the building laws of practically every city on the American continent prescribe that reinforced concrete members shall be calculated as freely supported—that is, steel shall be provided on the tension side to satisfy the equation, ⅛ WL, which those of you who are familiar with the mechanics of engineering will recognize as the value of the bending moment in a freely supported beam for uniformly distributed loading. The plain fact that continuity of stress is bound to exist is very largely ignored. The new building code of the City of Philadelphia, issued in November, 1907, is the first one to require provision for continuity stresses. Yet, it has not, in my opinion, gone far enough, in that no allowance is made for continuity, beams being still required to be figured as freely supported. To show you the great difference in the amount of steel necessary, I would ask your attention to the following diagram, which represents approximately the character of the stresses realized in beams continuous over several supports. You will note that to all practical purposes, the bending moment in mid-span may be represented by the equation 1/24 WL, and the bending moment over the support,



End span. Intermediate spans.

Adjust l' to l to make $BM' = BM^3$

$BM^2 = \frac{1}{12} w l^2$ (near enough)

$BM^3 = \frac{1}{24} w l^2$ (" ")

$BM^4 = \frac{1}{8} w l^2$ for freely supported

Diag I

known commonly as the negative, bending moment, by the equation 1/12 WL. Obviously, then, to calculate beams as freely supported that in construction are bound to be continuous, is to provide three times as much steel in mid-span as the actual stresses require, and, if along with this error, the negative bending stresses are partially, if not wholly ignored, there is uncared for a stress represented by 1/12 WL over the support, and the plain result is, if the member is ever loaded to its calculated ultimate carrying capacity, parting of the beam over the support is inevitable. Moreover, in practically every failure of a reinforced concrete construction this neglect to provide for continuity stresses has been largely responsible for collapse. This fact has not been sufficiently realized, for, in nearly every case, the cause of the failure has been assigned to premature removal of the centres. On the contrary, premature removal of the forms has not been the cause of the difficulty, but, has only brought to light, defects in design and installation. Like charity, ''it covers a multitude of sins.'' In nearly every case, failure would have been either entirely prevented, or, not been nearly so extended, if proper provision had been made for negative bending stresses.

Bearing the foregoing facts in mind, let us proceed to examine practically a typical reinforced concrete layout, and to adapt a system of reinforcement to best meet the conditions, which may be summarized as follows:

(1) That it will provide for all stresses horizontal and inclined.

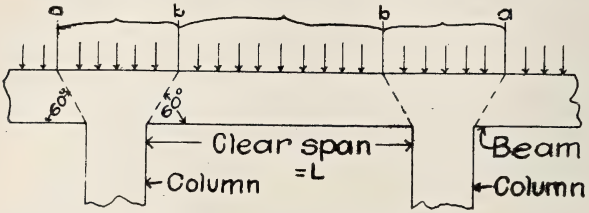
(2) That is will permit of the use of plain bars without the necessity of shop fabrication.

(3) That it will permit of easy and rapid, and, therefore, economical and safe installation.

Let us examine the first condition. In all failures of concrete beams wherein only horizontal reinforcement has been provided, the first sign of yielding has been a diagonal crack extending upward and outward at an angle of between 45° and 60° horizontal from the edge of the support. This is commonly known as failure by sheer; correctly speaking, it is failure in diagonal tension, for pulling apart of the concrete along the diagonal line above mentioned which defines the region where a reversal of tensile stresses from the bottom of the beam to the top ensues. Evidently this failure can be prevented by providing sufficient diagonal steel normal to the plain of separation to care for the stresses, tending to disrupt the beam at this point. How shall we ascertain the amount of these stresses and provide for them to the best advantage practically—this is the issue.

Let us examine for an instant a plain concrete or masonry footing with superimposed column. Now it is a well-known fact that if the footing slopes off from the edge of the column at an angle of approximately 60 degrees with a horizontal, the internal or cohesive strength of the material is sufficient to develop the full bearing value of the footing without danger of cracking. A concrete footing of this design would obviously need no reinforcing. The analogy is close between this case and an earthen embankment. If the soil slopes at the so-called angle of repose of the material, no restraining wall or other means is required to hold the earth in position; so, in a concrete footing, if the slope does not exceed the angle of friction of the material, no reinforcement is required

Now let us consider the footing and its column inverted. Have we not then the same condition as is realized in every reinforced concrete construction? It is perfectly apparent that the portion of the beam over the support encompassed by the 60 degree lines is capable of transmitting its load into the support without the assistance of any metal. This reduces the loading on the beam which produces bending in mid-span to the portion between the upper ends of the same 60° lines. We need therefore provide reinforcement in the lower side of the beam to care for the bending moment produced by this reduced loading over the clear span between supports. The tendency obviously is for this mid-portion of the beam to slide out of position, even though the horizontal tensile stresses may be adequately provided for. This explains the failure due to diagonal tension of beams in which horizontal reinforcement alone is provided. To counteract this tendency, the simplest plan seems to be to bend up some of the horizontal steel, where it is no longer required to take horizontal tension, and carry it through this plane of diagonal tension normal to it in amount sufficient to take care of the component stress along this plane. This is made clear on the diagram. This diagonal steel must, of course, be anchored securely at either end in order to be effective; at its lower end it is a part of the horizontal steel which very effectively anchors it; at the upper end equally as effective anchorage may be secured by carrying the same bars across the support and down into the adjacent span. As an additional precaution this end may be hooked, a device which somewhat assists the bond. Or, as is our practice, the bar may be carried down into the adjacent span and used there, one span being thus anchored against the other and an absolute tie provided across the support.

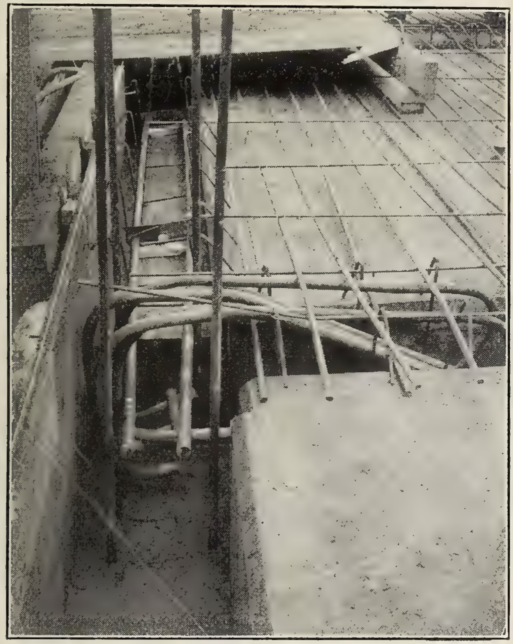


Load "a" to "b" produces no bending
Load "b" to "b" produces bending over span =L onl

Diag II

In a series of spans by using this system of double length bars, in alternation, absolute continuity of the reinforcing is practically insured throughout the construction. This feature not only is an effectual guarantee of safety, but it increases the carrying capacity considerably. A further advantage afforded is the early removal of forms possible which is an economical factor not to be made light of.

The similarity between the foregoing method of placing steel in beams and the catenary curve, which is the form assumed by a loaded cord freely suspended, is apparent; and in fact, if the steel were placed in exactly this position and provision were made for the full development of the steel at every point, the analogy would be perfect. Then the steel would be at all points in correct position to assume all tensile stresses leaving the concrete to act only in compression and to restrict the steel to definite lines of action.



Typical Reinforcement for Columns and Beams
F. H. Fleer Building, Toronto

There is, furthermore, an analogy between this method of placing steel and a parabolic bow string truss. Those of you who are familiar with the mechanics of bridge construction will recall the remarkable property possessed by the parabolic bow-string truss in that there is uniform tension throughout the tension chord and uniform compression throughout the compressive chord of the truss.. This fact is of marked economic advantage, inasmuch as it permits of the use of the same section of metal throughout. The same advantage obtains by simulating the parabolic truss in designing reinforcement for reinforced concrete.

It will be apparent that if the steel were placed to satisfactorily fulfil the catenary principle, no further reinforcement in the beam would be needed, which would theoretically be correct. However, in practice we find it advisable to use vertical stirrups throughout the member, although theoretically their presence might be considered superfluous. There are two reasons which justify the use of stirrups in this connection. Firstly, that, inasmuch as T-beams are almost invariably realized in actual construction, economy justifies the use of narrow deep beams which calls for the use of a certain amount of vertical steel to tie the compression flange to the rib. Especially do stirrups become an absolute necessity when in the course of installation it becomes impossible or impracticable to pour the soffit of the beam and the superimposed slab which forms its compression flange at the same time. Stirrups of the proper type and liberally spaced throughout the length of the beam become in this instance an effectual agency in unifying the parts of the beam. Secondly, stirrups are a practical advantage in that they may be utilized to carry, as in a saddle, the main reinforcing bars. It might be added that in general it is a good principle in dealing with concrete to have some steel running in all directions horizontally, diagonally and vertically; and, moreover, vertical stirrups are indisputably an addition to the strength of the beam because of their action as vertical tension members of a Howe truss system. A system of reinforcement along these lines evidently meets the first criterion of an ideal system, namely, that it provides for all stresses.

Placing Steel for Floor Slabs and Beams

The second condition to be satisfied is that plain bars only need be used as they come from the rolling mill without the intermediate step considered indispensable by many engineers of shop fabrication. In the early days of reinforced concrete construction, and, very largely yet to-day, little or no attempt is made to secure accurate placement of the steel, and as a natural result wide prejudice has been engendered in the minds of engineers against so-called loose bar installations. This problem, we believe, has been satifactorily solved in the system now being explained. With the aid of a few simple accessory devices which are made clear on the accompanying illustration we believe we have made it entirely possible to use plain bars without shop fabrication, without undue expenditure of time and money in the field, and with absolute assurance that all steel will remain in position intended throughout the operation of installation. Moreover, this is accomplished without excessive expense for inspection, and the possibility of mistakes is also largely reduced.

The third criterion follows naturally—certainly a system that satisfies all theoretical conditions, ensures accurate placement of the steel, has the possibility of error reduced to the minimum, and that requires less inspection than any other system that has come to the writer's attention, will be easy and rapid, and, therefore, economical and safe in installation. The principle followed out in constructing a reinforced concrete floor under this method is, briefly, as follows: Place each item of the steel in logical order, and when once placed and inspected know that it will stay there, then, when sufficient steel has been placed for a day's work in advance, the operation of pouring concrete may be begun and continued without interruption.

This method not only ensures correct work, monolithic construction throughout and a better quality of workmanship, but, by eliminating the element confusion in a large measure, greatly increases the effectivenes of the organization, thereby making possible more rapid construction and needless to say more economical. In a typical instance, for example, in an eight storey factory building in Philadelphia, of approximately 10,000 square feet to a floor, stories were added at the rate of one in every seven to ten days throughout the job. Interruptions of weather alone delaying. The cost of the steel in position exceeded very little, $40 a ton reckoned from a base of $34 a ton; and the total cost of mixing, hoisting, placing and tamping the concrete averaged, under favorable conditions, close to forty cents a cubic yard and never exceeded seventy-five. A twenty-two foot span girder in this building, when tested, to three times its calculated carrying capacity deflected less than three-sixteenths of an inch, which is about half the allowable deflection prescribed by good practice, namely, 1/800 the clear span. The loading was so arranged as to obviate any arching that would defeat the spirit of the test. The slabs in this building, when loaded three times their capacity, showed absolutely no indications of deflection. In another building constructed similarly, a floor designed according to the city building law for 120 pounds live load, was loaded up when only thirty days' old to over 600 pounds a square foot and gave no sign of yielding whatsoever.

In conclusion, I would say that what has been presented to you in this paper represents the honest attempts of engineers having neither hobbies nor prejudices, but seeking only to secure with the simplest means at hand, the most practical system of reinforcement. It has been adopted widely in Philadelphia, and is being used in the reconstruction of the Bridgeman Brothers' factory, which collapsed last spring. While not by any means ideal, it seems to be in the way of progress, and the results obtained are certainly a justification.

Gentlemen, I thank you for this opportunity and for your warm interest, kind attention and courtesy.

SEWAGE DISPOSAL FOR INLAND TOWNS

MARCEL PEQUEGNAT, '08

Mr. President and Members of the Engineering Society:

The question of sewage disposal is one which, at the present time is confronting many of our engineers, especially municipal engineers, and it seems quite in place to open a discussion on the subject here, in the Engineering Society. I certainly feel quite incapable, with the little experience I have had, to do justice to the subject, but I hope that this paper will prove at least of some small interest to you all.

Towns and cities bordering on large bodies of water, lakes or rivers, do not experience the real difficulty of sewage disposal. It is the inland town that has to face the trouble and a very serious one it is. Very few towns are so unfortunate as to be entirely without flowing water but in most cases it amounts to a little creek, perhaps ten to fifteen feet wide, hardly deep enough for the little boys to swim in, and this is the stream that must unburden the town of its sewage, no matter how large that town may be.

There are many reasons which forbid allowing the pure sewage to enter such a stream, and even larger one; I will enumerate five important ones.

1. The contamination of water and ice supplies.
2. The destruction of fish.
3. The danger to health.
4. Legal rights of land-owners along the course of the stream.
5. Unsightly appearance since stream becomes merely an open sewer.

It is therefore very important that an inland town finds some method of purifying the sewage before allowing it to enter the stream and thus free themselves from any trouble with the people in the neighborhood. Before the Town of Berlin put in its present system, which I will describe briefly a little later, they had to face this difficulty; dozens of farmers along the course of the stream sued the town for damages, and as the town could not put in any defence, it had to pay claims to the amount of $20,000.

There are several methods used for the purification of sewage, but the septic tank with sand or gravel filtration seems to be taking the upper hand, and I shall describe such a system.

The simplest way will be to take a definite system, and trace the course of the sewage through it. The Town of Waterloo affords a good example.

Up to the present the sewage has been deposited on a farm about a mile from the town. The ground had been graded to form filter beds, but they were not of the right material, they got choked quickly and the sewage was practically dumped into the stream without any filtration. The town saw trouble ahead and accordingly proceeded to remedy matters. A sewage commission was formed and they lost no time in getting to work. The intention at first was to use the old farm, build it up with gravel beds and put in tanks, but they were held up for gravel, besides the beds were not high enough to allow for proper filtration. They accordingly looked for a better site, and found one with gravel about a mile farther down the creek. They purchased the farm, which had hills on either side the creek, and then came to an agreement with the farmers along the line for a 15′ right of way for the trunk sewer. The town has the right to build the sewer, and enter their places at any time for repairs, etc. This part completed, the plans for the farm were prepared, the size of the farm was to be sufficient to look after the sewage for many years to come.

The Town of Waterloo has a population of about 4,000 and the sewage to be disposed of amounts to 250,000 gallons in twenty-four hours. It required a 15″ pipe, having a fall of 2½″ per 100′, to carry this sewage to its destination, and to provide for an increase in the future. The stream falls slightly faster than this and in this way about 3 or 4 feet of extra head is obtained at the works.

The fall of the sewer being so slight it is very important to lay every pipe exactly to grade and to see that all joints are made as smooth as possible. To get the grade the engineer plants solid hubs every 200′ and over these erects bridges at some definite height, say 8′, above the grade of the pipe, then by using a boning rod, as they call it, which is exactly 8′ long, the contractor can get the exact level of each pipe between the stations by sighting over these bridges. Manholes are built at each bend of the sewer for inspection and ventilating purposes. The contractor is supposed to make every joint water-tight, the sewer not being built to drain the land, but it is almost impossible to watch them lay every pipe, especially if the inspector must supervise gangs at some distance apart. A good way of getting over this difficulty is to let the contractor understand that he must find where the leaks are, if water enters the pipe and shows itself at the manholes, and it is therefore to his interest to see that the joints are right. In a swampy place where a foundation has to be built to support the pipe the contractor is allowed extra, at a price, generally per cubic yard, given in the agreement.

The disposal works are situated on the opposite side of the creek from the trunk sewer, and the sewage has to be taken across. In order to do this the sewage passes through an inverted syphon. The sewage is freed from sticks and other such matter by passing through a cast iron screen; it then drops into a manhole 9½′ deep and crosses below the stream through a 15″ cast iron pipe, and again rises in a manhole at the mouth of the septic tanks. There is a slight danger of this inverted syphon becoming blocked up, but this is overcome by having an opening directly into the sludge drain, which will be described later. The sewage has about six feet of head to shoot it through the syphon.

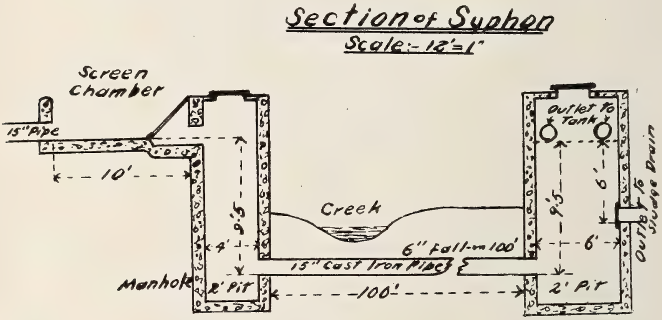


Fig. 1

The sewage then flows into the septic tanks. There are two separate tanks side by side, so that while one is being cleaned out the other can be kept in use. The sewage first passes into a "grit chamber" where the sand, etc., is deposited, being heavier than the ordinary sewage. This chamber is 26′ long, 10′ wide and 6½′ deep. The sewage then passes into the septic tank proper. This tank is 125′×26′, about 6′ deep, having a capacity of 120,000 gallons. Here the sludge settles to the bottom, and the remaining fluid drops over a level overflow into the distributing chamber, which distributes it to the different filter beds. Each tank is provided with baffle boards to insure the settling of all the sludge. The tanks are built large enough to hold all the sludge for the entire year, and thus have only to be emptied once in that period. The grit chamber, being small, has to be emptied after every heavy rainfall, for at those times much mud, sand and small stones are washed down through the sewers. The floors of the tanks are slightly inclined, so that the sludge can flow into the sludge drain, pass under all the filter beds and be deposited on a special bed, having an elevation below that of the bottom of the tank.

This sludge is allowed to dry out, and then is raked up in heaps and burnt. In some parts of the country the farmers are eager to obtain the sludge for fertilizing purposes, but in that district they seem to be afraid of it and it must therefore be disposed of as described.

Sewage, as you all know, is almost entirely organic matter, having some useful bacteria and some of no use, and even dangerous to life. The useful bacteria act as scavengers for the others.

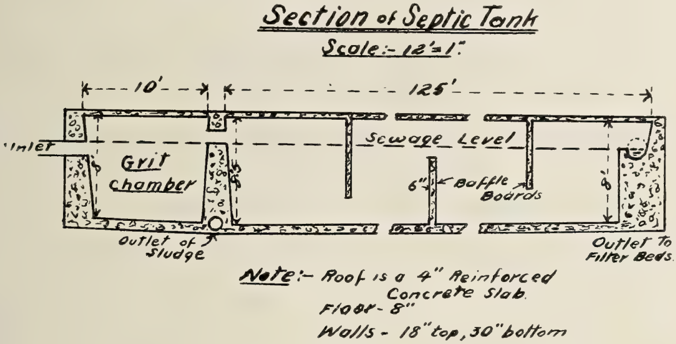


Fig. 2

The septic tank is an arrangement for nursing bacteria which act in this way on organic matter, and to promote fermentation. It gives them a chance to act rapidly and reproduce their kind, in the tanks by running in nutritious sewage. The greater part is converted into CO_2 marsh gas and H, which escapes into the air. The rest settles down at the bottom, as harmless sewage, and is disposed of as already described. The septic tank is ahead of the precipitating tank, *i.e.* treating the sewage with lime or some other substance, for in that process nearly all settles and more room is required.

The bacteria of disease may or may not be destroyed by bacteria in septic tanks, but they are solid and settle down in the tank, so the septic tank is at least a great defence.

From the tanks the sewage is run by means of distributors and carriers over the filter beds. They cover an area of about 3½ acres, the whole space being divided up into six beds. These beds are constructed as follows: The sub-grade is first formed, having a slight slope toward the effluent drain. The drain is laid through the centre of the bed of 8″ field tile, and from this 4″ tile are run to the edges every 20 feet. This formed a good subsoil drain to carry off the effluent after filtration. Above this is deposited a layer of gravel and sand, having an average depth of four feet. the surface being made as level as possible. A cement carrier is run across the centre of the bed, thus distributing the sewage evenly over the entire surface.

If a filter bed of this kind is treated properly it will last for a very long time before it is choked up. After being in use for some time, it needs a rest to rid itself of the impurities it has taken in, and after a rest it is just as fit as before to carry on its work of filtration. The filtrate is then carried through the effluent drains to the creek, but now in such a condition of purity as to cause no trouble to man or beast.

The system described is entirely carried on by gravitation, the expense being considerably less than where pumping has to be done, especially since all the material was so close at hand. The cost of the work might be of interest to some; the contract price for the making of the 3½ acres of filter beds was about $11,000, and for the septic tanks and connections $6,500, the town supplying all the iron and steel necessary in the work. The work is not yet completed.

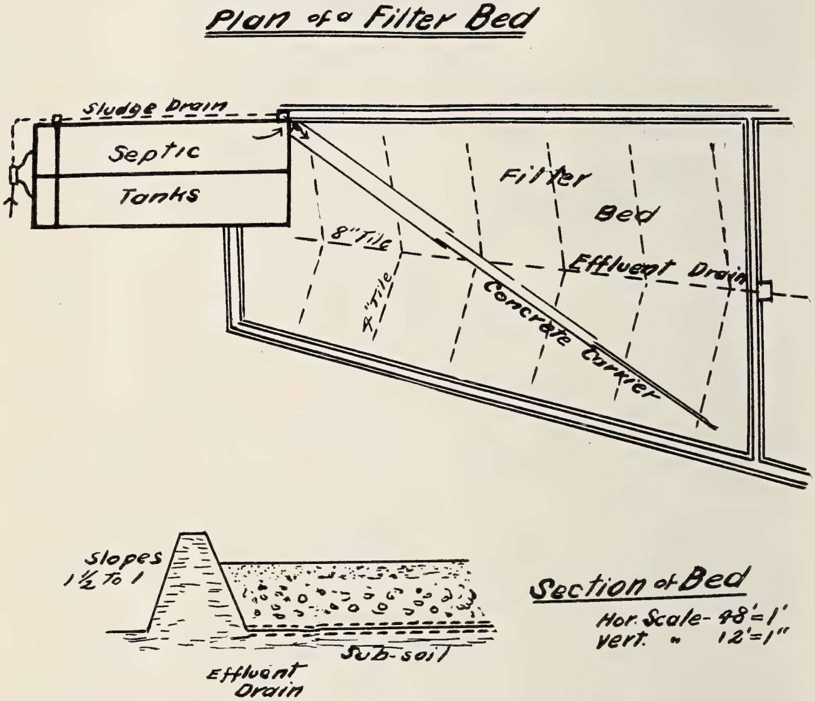


Fig. 3

My travels have not been extended, and you will have to excuse me for keeping within the bounds of my own native county; but I believe that a little information of the system installed in Berlin, Ont., and which has proved a great success, will be of interest.

Berlin also had an old sewer farm of the style of Waterloo's which had long since seen its best days, and before the new system was constructed the sewage practically emptied into the creek, and hence the trouble with the farmers in the neighborhood.

The population of the town is about 13,000, and the amount of sewage is from 600,000 to 700,000 gallons in 24 hours, the trunk sewer being only 18″. The tanks are composed of two septic and two storage tanks, total size being 300′×75′ and 6½′ deep, a capacity of 900,000 gallons. The pumps cannot be continually in motion, hence the need of storage tanks, to hold the fluid sewage after it passes through the septic tanks. The sewage is pumped by means of two centrifugal pumps, each of 1,000 gals. per minute capacity, direct connected with a 50 h.p. induction motor, and there is a special pump for pumping up the sludge of capacity 500 gals. per min. The force main is a 14″ cast iron pipe, a length of 2,000′, and rises in that distance to a height of 60′. In this way the town makes use of natural sand hills, which have been levelled off for the filtration of its sewage. There are 10 filter beds, having a total area of 14 acres. The sewage has thus to soak through considerable sand before it reaches the creek 60′ below, and hence reaches a state of great purity. Chemically the effluent from the Berlin farm is purer than the water the people drink, and the water there is not much worse than in other places. A gang of men were laying a tile drain to drain off some of this effluent, and they used it freely as drinking water, not being satisfied with the water brought them from a neighbouring well.

As I have said before, tanneries, etc., cause the greatest nuisance, and to overcome this the town has passed a by-law forcing all such institutions to construct settling tanks of their own, and to pass the sewage through them before allowing it to pass into the town mains.

As I have said before, Berlin's system has proved to be a great success, but there is at the present time a small source of trouble. Part of the filtrate from the filtration beds is finding its way over the land of the adjoining farms. They have attempted to stop it, by means of sub-soil drains, run around the beds, but they do not seem to catch the water. The farmers are complaining of wet land, so it will probably be necesasry for the town to purchase the land in question, which is not a very serious matter.

Many are of the opinion that all the water from the street, etc., passes into the sewer, and has to be treated along with the rest of the sewage. This is, however, not the case, and were it so, the disposal plant would need to be considerably larger. The storm water, and even the cellar-draining system, has pipe lines of its own, and is turned into the creek at its nearest point.

I consider it agreat honor to have had the privilege to give a paper before the Engineering Society, and I must thank your worthy President for giving me this opportunity, and trust that it has not taxed your patience too far.

STADIA TOPOGRAPHY

W. TREADGOLD '05

The adaptation of plans to the purpose in view constitutes the aim of the civil engineer. However general in scope a method may be, it is modified in characteristic details by ever varying requirements of natural conditions of the project and of the necessary cost. The appreciation of the conditions involved characterizes the successful project, whether in the survey, design or construction of engineering work.

Realizing this, I will endeavor to consider separately and independently the different methods of executing a topographical survey and point out how far they are effected by conditions of amount of detail required, cost and general adaptability of the country to be surveyed.

Originally, the prevailing opinion regarding the use of the stadia was that, at best, it would answer as a rough expedient, comparable rather to pacing than to chaining as regards accuracy. However, among those familiar with its use its great value has been recognized and its adoption advocated where precision of not more than 1 in 1200 would be allowable. That it is more accurate than chaining, even after the correction of several large errors caused by a miscount of the number of chains, is evidenced by its use not only in the smaller surveys, such as location of possible reservoirs and conduit lines for waterworks and sewage systems but also on large extended surveys such as made by the governments of the United States and Canada.

The principle of the method depends upon that of similar triangles or upon the fact that the lengths of parallel lines which subtend a constant angle are proportional to their distances from the vertex of the angle, or, to be more definite, if two parallel wires be placed in the focus of a telescope and it be directed to a graduated rod held so that its length is perpendicular to the line of sight of the telescope, the length of the rod between the points

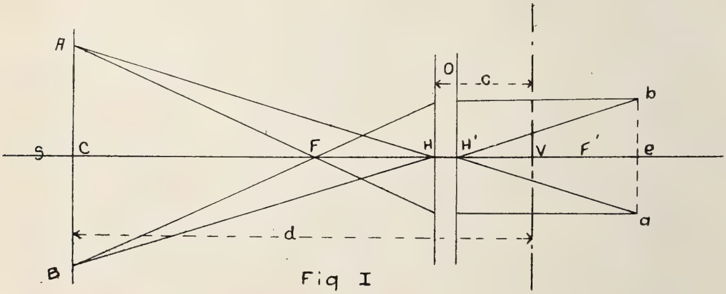


Fig I

covered by the wires is proportional to the distance of the rod—from what point must be determined on optical principles.

In the figure, $A\ B$ represents the graduated rod, O the object glass of the telescope, of which H and H^1 are the principal points, F and F^1 the focal points; a and b are the positions of the stadia wires. The diagram shows that A and B are the points of the rod intercepted by the cross wires.

Let $S = AB =$ length of rod intercepted by cross wires.
$e = ba =$ distance between cross wires.
$f =$ focal length of the objective.
$d = ev =$ distance from the position of the rod to the centre of the instrument.
$c = HV =$ distance from the object glass to centre of instrument, V being the point in which the vertical axis of the instrument intersects the axis of collination if produced upwards.

By similar triangles $F\ A\ B$ and $F\ D\ E$

$$\frac{C\,H}{F\,H} = \frac{A\,B}{D\,E} \text{ or } \frac{d\text{-}f\text{-}c}{F} = \frac{S}{e}$$

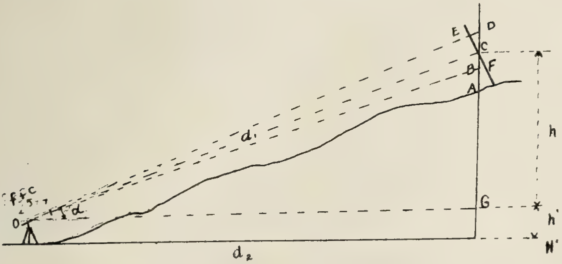
or

$$d\text{-}f\text{-}c = \frac{f}{e} S = KS$$

when K is the constant ratio of the focal length of the objective to the distance between the stadia wires.

Thus we see that the length of rod intercepted between the stadia wires is proportional to the distance of the rod from the outer principal focus of the objective of the telescope.

This applies to a level sight or to an inclined sight in which the rod is held so as to be perpendicular to the line of sight. It is usual, however, to hold the rod always vertical, irrespective of the inclination of the telescope.



Suppose
$o\ c = d_1 =$ inclined distance from rod to instrument.
$o\ G = d_2 =$ horizontal distance required.
$C\ G = h =$ difference of elevation of O_1 and C.
S_1=part of rod intercepted when held perpendicular to the line of sight.
S=Part of rod intercepted when held vertically.
$\alpha =$ angle of inclination of the telescope.

Since $O\ E$ and $O\ F$ are very nearly perpendicular to the line $E\ F$ then $S_1 = S \cos \alpha$

But we have already proved

$$d_1 = (f + c) + K\ S_1 = (f + c) + K\ S \cos \alpha$$

in the triangle $o\ c\ G$ we get

$$d_2 = d_1 \cos \alpha$$

and

$$h = d_1 \sin \alpha$$

Hence

$$d_2 = (f + c + K\ S \cos \alpha) \cos \alpha$$
$$= (f + c) \cos \alpha + K\ S \cos^2 \alpha$$

also

$$h = (f + c) \cos \alpha + K\ S \sin \alpha \cos \alpha$$

If then we are given the elevation of the point of set up, H^1, measure the height of instrument h^1, m the reading of the middle cross wire on the rod and H the elevation of the point sighted we get $H = H^1 + h^1 + h - m$.

In order to get results we must obtain the values of the constants f and c.

f is the focal distance of the object glass and is obtained by measuring the distance from the object glass, when the telescope is focussed on a far distant point, to the intersection of the cross wires.

c is the distance measured from the intersection of the horizontal axis and axis of collination to the object glass.

$K = \frac{f}{e}$ and the spacing of the wires is made so that the value of K will equal 100.

There are many designs for the stadia rod and in each it is essential that they should combine simplicity, clearness, distinctive divisions and subdivisions and efficiency in indicating the shorter distances very accurately and in giving great distances readily. That it should be divided into true unit lengths, such as feet, is desirable for many reasons. It makes impossible any error due to an accidental interchange of stadia rods among transits; any stadia rods not especially constructed for the particular transit may be used in case of emergency or desirability, viz., level rods may be used for stadia readings for stadia railroad preliminary surveys. There are also other considerations that make this almost a necessity; the one that the distance above the stake at which the middle wire stands when the vertical angle is measured may be read in the linear distance; the second, that error in the stadia interval, occurring either from a change in the cross wires or from a subsequent determination indicating that previous determinations have not developed the true and exact factor, may be corrected without the complete change of the stadia rod divisions, which would at best consume several days of delay and careful work.

However, very often cross wires are placed in the diaphragm by the topographer himself and to suit the spacing of the wires he graduates the rod in the following manner. He measures carefully some convenient distance from the instrument, say 600 feet, and marks on a blank rod the length intercepted between the stadia wires; a sixth part of that length is then the unit according to which the rod is to be graduated and the number of those units contained between the stadia wires when the rod is held at any distance from the instrument will indicate that distance in hundreds of feet.

We have seen from our formulae

$$d = (f + c) \cos \alpha + K S \cos^2 \alpha$$

and

$$h = (f + c) \sin \alpha + K S \sin \alpha \cos \alpha$$

but it is a very common practice in some quarters to assume that the distance is directly proportional to the space intercepted by the cross wires, thus neglecting the quantity $(f + c)$ whose value ranges from 1.00 to 1.25 feet generally.

In so doing we obtain a new value for the constant K by measuring out a distance which will be equal to about the mean of the distances expected to be measured.

It will be found that this gives errors in the true distances, which in any case do not exceed $(f+c)$, some of which will be positive for distances less than the measured distance and negative for distances greater and the tendency will be for the errors to cancel one another.

Some instruments are provided with an additional lens called an anallatic lens, which moves the vertex of the reading angle from the outer principal focus up to the centre of the instrument thus enabling you to read directly the distance the rod is held away, thus getting rid of the constant quantity $(f+c)$—with a lens of this kind in the telescope the approximate values of distance are correct. This instrument, which, by the way, goes under the name of Tacheometer, has one disadvantage and that is the loss of light necessitated by addition of the extra lens.

The basis of the detailed topographic work is usually a traverse line, the stations being marked by hubs in the ordinary way and the work generally involves the instrumental location and determination of the elevation of all surface irregularities and the positions of roads, trails, towns, ranches, wood, cultivated land and water. The datum from which all elevations are reckoned may be assumed with reference to the original station. The horizontal angles are best measured by the traverse method, that is, azimuths are carried continuously and measure the deviation from the meridian. For measuring vertical angles the best graduation is one that gives the zenith distance of the point sighted thus avoiding the necessity for distinguishing between the positive and negative altitudes. The degrees of the two halves of the circle number from a common zero in opposite direction to 180° and it is so placed on the axis that when the sight time is vertical one vernier reads zero and the other 180°; thus on sighting any point the one vernier will give its zenith distance and the other its nadir distance in either position of the instrument. However, as this graduation is seldom met with it is assumed in the formulae used, that α is the altitude of the point sighted. On a small survey the party would consist of a transitman and two rodmen and one axeman, but on an extended survey like that, say, of the boundary between Mexico and the United States or Canada and the United States, there are several parties to do the work. On boundary work topography is taken for two miles on each side of the boundary line. One party would work along the boundary line itself taking distances and elevations, this line being considered as the true basis for all after work, a second and third party would then do detail work on each side of the boundary. These parties would start with the bearing of the line at a starting point of the base line and run out a traverse at right angles until they had gone as far as necessary and then return by another route thus checking back on the original base line by making a complete circuit. At each setting of the instrument measurements would be taken on all the distinct points of the ground and so the greater number of side shots taken the greater information you would have and the map would then furnish more completely all the detail. The occasional remoteness of the work from available camps, the very rough and difficult nature of the regions encountered, sometimes makes it advisable to withdraw the party engaged in running out the base line from their usual work to reinforce the others, all parties then working advantageously together on pure topography.

Occasionally ground is covered by means of a method of intersections. In this region there are say several commanding peaks below which lay the ground in all its irregularity, the general procedure here consists in the establishment of station signals on those commanding peaks and from numerous stations on the boundary the base line transitman will take azimuths and vertical angles to these signals from which the location and elevation of each station is computed; then these same stations are occupied two at a time in such order as to give the best intersections on points to be located. An engineer with a flagman, using horses where the country will permit, will traverse an advantageous area; the flagman signals at each necessary point of the area and the engineer makes a contour sketch of the ground showing the position of the points from which the signals are made, at the same time the two transitmen at their stations watch the flagman and on a signal from him, each takes the azimuth and vertical angle to his signal held vertically on the ground, the engineer and transitmen all note the time of each sight to have a check distinguishing corresponding observations. Topography taken in this way is not capable of the accuracy of the usual method but at times is advantageous and is used to facilitate and hasten the work.

This then represents in a small way the manner in which a stadia survey is often carried out. Experience tells us that for general economy, adaptability, and efficiency it is unequaled and as a consequence on topographic and railroad surveys, canals and other public works this method is rapidly superseding all others.

APPLIED SCIENCE

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Editorial

Do the University Alumni Lack Esprit de Corps?

The critics of the University in past years claimed that among the many things it lacked, was a proper, vital, esprit de corps both among the graduate and undergraduate bodies. They claimed that with the great mass of the Alumni there was no bond of sympathy between either themselves or their Alma Mater; that, to the average graduate, to be a Toronto man had no special significance; his college days were merely a memory, no different from other associations; that the average graduate felt in no way bound to keep in touch with his Alma Mater; that, at most, his interests went out to the members of his own faculty and his own year; those of other faculties and other years were of no more interest to him or had they more claim on him than the natives of the Fiji Islands. In other words, Toronto University had not put its stamp on them.

Does the School Lack Esprit de Corps?

Just how true the above is concerning the University as a whole we are in no position to judge. One thing is certain, however, that it is not true of the "School." Once a School man always a School man, seems to have been the motto. The reason for this is obvious. The men in the Faculty of Applied Science have a better opportunity of becoming acquainted with each other, in the field and drafting rooms, than those in other Faculties. Again, in early days when attendance was small we had to make a fight for recognition. "Toike, oike, Toike, oike," often assembled the boys either to battles of offence or defence when shoulder to shoulder they fought for the honor and glory of the School. Just how much effect these scraps had on the cementing of friendship and the arousing of that feeling of mutual help which all School graduates carry with them into the world is hard to say, but that it has had some no one will deny. Once a School man quoted, as he said from Shakespeare: "Verily, when one or two School men have been hired in one place, you shall soon see another one."

An Employment Bureau

What our graduates have done for each other in the past in the matter of furthering each other's interests professionally, and what has been done by the staff with a limited organization, the Faculty and Engineering Society propose to take up systematically in the future. The publication of "Applied Science" was one of the first steps in the scheme. In the first place we wished to get the addresses of all the graduates, to get in touch with them, and, we hope, to keep in touch with them in the future. The response in the shape of subscriptions has been very gratifying.

In the course of the next few weeks every graduate will receive a blank form requesting information concerning himself and his professional career. We purpose starting a card index of all our graduates and undergraduates together with all available information concerning them. This information will be regarded as strictly confidential when necessary or desirable.

Repeatedly we have firms and individuals writing in for competent men on engineering works and we have been without the necessary information to recommend suitable graduates to them. Frequently we have been able to secure positions for our men who were thoughtful enough to keep us informed of their experience and whereabouts.

It is expected that when we have completed this proposed index and have acquainted the commercial world of the fact, that an important work will be done in this department.

The professional record of all graduates is wanted even if they have no intention of making use of the employment department. We want to know just exactly what you have accomplished; to show that our men measure up with those of other universities. We wish to show that we can justify our existence—that the money spent by the country in educating engineers has been well invested in furthering the development of the country.

Request for Information.—On another page there is a list of men whose addresses we have been unable to verify in the last year or two. Examine the list carefully and if you can supply the information as to their present whereabouts—if living—let us know immediately.

The Future of Niagara Falls

In the light of the discussion at the present time, of the Hydro-Electric Power Commission Policy and municipal ownership of transmission lines for electric power, we ought not to lose sight of the issue raised about a year ago on the question of taking water from the Niagara River for power purposes.

It will be remembered that in 1905 there was throughout the United States a widespread public sentiment against the granting of any further privileges of the withdrawal of water for the developing of power.

This sentiment was no doubt greatly fostered by the appearance at that time of certain magazine articles, some of them grossly untrue, calling upon the public to petition the government against such grants and suggesting at the same time that international action be taken to prevent any further grants in the future, in order to prevent complete devastation of the Falls. To illustrate the unreliability of the magazine articles above mentioned it will be sufficient to quote from one of these. The statement was made that further withdrawals of water from Niagara River would mean a lowering of the level of the Welland Canal and thereby be a menace to navigation. When it is understood that the point on the Niagara River at which water for power development is taken is a short distance above the Falls and many miles below the intake of the Welland Canal on Lake Erie, the fallacy of the above statement is apparent.

However, public sentiment in the United States was aroused by such articles and strong appeals were made to the Governments of both the United States and Canada to intervene on the ground that the river was an international stream. The United States Congress and Senate in 1906 passed an Act called the "Burton Bill" which provided for the control and regulation of the waters of Niagara River and the preservation of the Falls, this Act to remain in force for three years from date of passage.

Should Canada Sacrifice Her Rights?

At the present time considerable pressure is being brought to bear on the Canadian Government to co-operate in the restriction of withdrawal of water. At first sight the scheme to the average Canadian looks quite just. The United States Government says: "We have restricted the use of this water for power purposes in order to preserve the Falls for future generations. It is a heritage which has been handed to us and we ought to pass it on unimpaired." But when you find the American Government more than willing to meet the Canadian Government half way, it is wise to go slowly. The truth of the matter is this. The American Falls is about six feet higher in elevation than the Horseshoe Falls and only a very small proportion of the flow of Niagara River passes over it. Any further development on the American side will be at the expense of the water passing over that fall and will mean a great impairing of its beauty. On the other hand, as the bulk of water passes over the Horseshoe or Canadian Falls, considerable development can still be done there, without in any way affecting the scenic beauty of either Fall, for the water taken at the Canadian side of the river cannot have any material effect on the American Fall.

If then the Government of Canada places a restriction on the development, it will mean giving up the tremendous advantage which the Canadian side of the river has by virtue of its location, over the American side, which, as has been shown, is at its limit with respect to development of power without materially injuring the American Fall.

No doubt legislation will soon be introduced into the House of Commons bearing on this point, and we as Canadians should see that we do not give up this great natural advantage at the request of the nation to the south of us. While it would be a mistake to issue wholesale charters for power development purposes, still with reasonable care a great amount of the water at present flowing over the Canadian Fall can be used to perform useful work and the natural beauties of the Falls at the same time be preserved.

WHAT WE ARE DOING

S. P. S. Electrical Club.

As is known by those interested in the welfare of this club, it is now in the second year of its life. Its chief aim is to give third and fourth students in mechanical and electrical engineering a chance to freely discuss, informally, engineering subjects of interest. Only those who have taken an active interest in the work done by this organization, or have taken part in such discussions, can fully appreciate its value. Anyone who wishes his views to bear weight must be able to present them in a clear and convincing manner and to be able to do this experience is necessary.

Another important function, and one much prized by the members, is the excursion held on Saturday mornings to the principal places of interest in the city and vicinity. These are taken on some Saturday convenient to the manufacturer or engineer in charge.

A short synopsis of the work done by this club since January 1st, 1908, will give a fair idea of its possibilities and the benefits derived by its members.

On January 23rd, C. H. Hutton, '07, read a very interesting paper on "Lightning Protective Apparatus," applied principally to transmission lines, showing by means of lantern slides several types of lightning arresters, explaining their peculiarities and respective merits.

On February 6th, the members were favored by a practical demonstration of "Wireless Telegraphy," by D. F. Keith, '07. The difficulties overcome by the most successful of the experimenters were pointed out and many of the resulting inventions explained. The use of wireless telegraphy in the commercial world to-day was shown and a good explanation given of the different systems in use at the present time.

H. Coyne, '08, gave an interesting and practical paper on "The Induction Motor" on February 20th. Its construction was traced from the manufacture of the separate parts to the assembled machine, the paper being illustrated by many excellent slides. The different modes of winding, the different styles of connections, and the practical theory was given. The paper ended with an explanation of starting compensators and their use in connection with the induction motor.

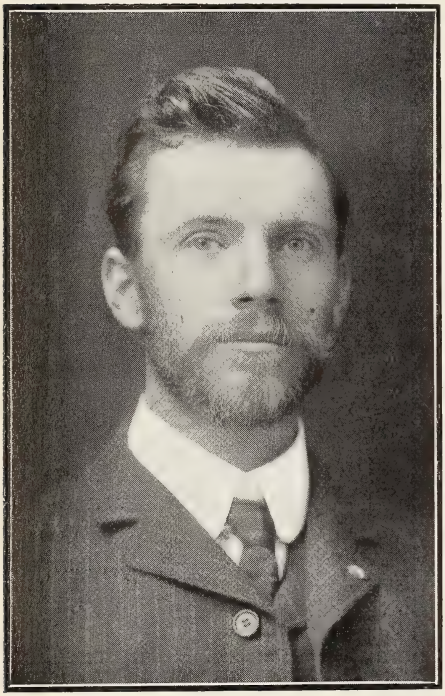
Saturday morning, January 25th, the Scott and Terauley Street stations of the Toronto Electric Light Company were visited.

WHAT THE GRADUATES ARE DOING

On this page we shall be pleased to publish *professional* news of any of our graduates.

The graduates are again reminded that this is as much their organ as that of the undergraduates. A great number have as yet not sent in their subscriptions; we lose two cents in postage on every magazine sent through the mails on account of this. Post your subscription at once. The Engineering Society will have to meet a deficit of five or six hundred dollars on the publication as it is, so do not let there be any unnecessary waste of money.

Readers of "Applied Science" will be interested to learn of a recent change made by Mr. Walter J. Francis, C.E., one of the graduates of the School of Practical Science. Mr. Francis has severed his connection with the Dominion Engineering & Construction Co., Montreal, of which, since 1906, he has been chief engineer and assistant manager, to open an office for himself in the Sovereign Bank Building, Montreal, as consulting engineer. For two and a half years subsequent to graduation, Mr. Francis was employed as assistant engineer on the Union Station works, Toronto, leaving in 1896 to become draughtsman and designer for the Central Bridge & Engineering Co., Peterboro. This position he resigned in 1897 to undertake for the Dominion Government, the design of the Peterboro Lift Lock on the Trent Canal, the first of its kind in America. This led in 1900 to a promotion to Division Engineer and later to Engineer of Lift Locks, which position involved the design of a second lock at Kirkfield, Ont., as well as the completion of the Peterboro lock, then well under way. The magnitude of



Walter J. Francis, C.E.

these undertakings and the ingenuity displayed in their design certainly place them among the interesting engineering works on this continent. On their completion in 1906, Mr. Francis resigned to take charge for Messrs. Ross & Holgate, of the construction of the 32,000 horse-power plant for the West Kootenay Power & Light Co. near Nelson, B.C. Returning to the east in the autumn of the same year, he connected himself with the Dominion Engineering & Construction Co. in the capacity indicated above. The World's Fair diploma that still hangs in the hallway on the second floor of the Engineering Building, was awarded for "remarkable excellence in topographical and architectural drawings" to two drawings, one of which was the work of Mr. Francis, then a student here. He graduated with honors in '93 and obtained the professional degree C. E. from the University of Toronto in 1900. In 1906 he captured the Gzowski medal, the gift of the Canadian Society of Civil Engineers, to the member submitting the best technical paper for the year. Mr. Francis is justly regarded as one of the brightest young men in the engineering profession in Canada. He is *par excellence* an expert on structural steel and concrete construction, and in this connection, his invitation by the Government Commission to examine the wreck of the Quebec Bridge and report thereon is significant. His experience during the past fifteen years has brought him face to face with almost all kinds of engineering problems. He is a member of the Canadian Society of Civil Engineers and of the American Society of Civil Engineers. We wish Mr. Francis every good fortune possible, and prophesy for him a career of growing usefulness and eminence.

We announce the formation of an engineering partnership between two of our old graduates, Herbert J. Bowman, '85, and A. W. Connor, '95. They will make a specialty of municipal and structural engineering, being the respective lines each has followed since graduation. Mr. Bowman is a member of the Canadian Society of Civil Engineers and an O.L.S. and a D.L.S. He was one of the founders of the Engineering Society. He has been practising as a municipal engineer in Berlin for twenty years, constructing a number of waterworks and sewerage systems and building many steel and concrete bridges. He has also been city and county engineer. He is a native of Berlin, being a son of the late I. D. Bowman, Esq., County Clerk and Treasurer. Mr. Connor is a double honor graduate in Arts, '93, and received the degree of C. E. in 1900. Upon graduation from the school he entered the service of the Hamilton Bridge Works Co., where he remained about six years. He was also with the Central Bridge Co. of Peterborough and the Canada Foundry Co. for about four years more. For the last three years he has been practising as a consulting structural engineer, being a member of the firm of Connor, Clark & Monds. He has designed many highway and railway bridges in steel and reinforced concrete, besides office and mill buildings and other structures. He is also an old Berlin boy, being the son of J. W. Connor, B.A., '64, for many years principal of the Berlin Collegiate Institute. The office of the firm is at 36 Toronto Street, Toronto, with a branch office at Berlin.

D. G. Park, '06, is with the Allis Chalmers Co., West Allis, Wisconsin.

The following graduates passed their O.L.S. exams.: H. W. Sutcliffe, J. L. Lang, F. W. Paulin, W. J. Moore, C. E. Bush.

T. R. Deacon, '91, is president and general manager of the Manitoba Iron Works, Limited, Winnipeg. He finds time to do a little consulting work. He was a member of the committee which recently brought in an exhaustive report on Winnipeg's water supply.

K. Rose and J. H. Chewett, both '88 men, are interested in the Evans Rotary Engine Co., Ltd., of Canada. They are having splendid success in placing their engines on the market.

C. W. Dill, '91, is senior partner of C. W. Dill & Co., engineers and contractors, Toronto.

C. A. Schofield, '07, is chemist at Niagara Frontier Laboratory, Buffalo.

W. J. Walker, '07, is a resident engineer on the C. N. Railway at Quebec.

A. W. Campbell, '06, is electrician with the Mond Nickel Co.

INFORMATION WANTED

We have been unable to verify the following addresses in the last year or so. Any information as to their present whereabouts would be greatly appreciated:

1885—J. F. Bleakley; E. E. Henderson.
1887—A. E. Lott; A. L. McCulloch; C. H. Pinhey.
1888—W. T. Ashbridge; D. B. Brown; J. Gibbons; B. Carey.
1889—G. F. Hanning; D. D. James.
1890—N. L. Garland; T. H. Wiggins.
1893—C. Forester; J. T. Laidlaw; F. L. Lash; A. L. McAllister; W. T. Main; W. Mines; R. Russell.
1894—H. F. Barker; A. E. Bergey; W. J. Herald; A. C. Johnston; J. E. Jones; A. L. McTaggart; C. J. Nicholson; R. T. Wright.
1895—W. M. Brodie; R. J. Campbell; H. S. Hull; H. L. McKinnon.

1896—J. A. McMurchy.

1897—W. A. B. Hicks; W. R. Smiley; M. B. Weekes; E. A. Weldon.

1898—J. E. Lavrock; D. Macintosh; A. E. Shipley; R. W. Smith; J. A. Stewart; H. L. Vercoe; T. A. Wilkinson.

1899—G. A. Clothier; C. Cooper; J. C. Elliott; W. E. Foreman; E. Guy; A. S. H. Pope; G. E. Revell; G. A. Saunders.

1900—J. H. Barley; J. E. Davison; G. W. Dickson; H. A. Dixon; J. C. Johnston; R. E. McArthur; S. M. Thorne; H. M. Weir.

1901—G. M. Bertram; J. T. Broughton; A. T. E. Hamer; F. C. Jackson; W. C. Lumbers; G. MacMillan; W. H. Stevenson

1902—J. M. Brown; W. G. Campbell; W. Christie; F. T. Conlon; H. V. Connor; W. M. Edwards; C. P. Henwood; D. M. Johnston; P. Mathison; R. S. Mennie; H. D. Robertson; H. J. Zahn.

1903—J. A. Beatty; R. E. George; J. G. Jackson; A. L. McNaughton; M. L. Miller; F. A. Moore; E. E. Mullins; J. P. Oliver; H. L. Seymour; J. Waldron; J. A. Welihan; N. D. Wilson.

1904—J. H. Alexander; T. D. Brown; J. W. Calder; C. A. Chilver; H. L. Chilver; P. C. Coates; S. E. Craig; J. G. Fleck; W. S. Gibson; J. P. Gordon; J. B. Heron; S. N. Hill; C. J. Ingles; P. V. Jermyn; O. B. McCuaig; G. G. McEwen; W. G. McFarlane; C. P. McGibbon; D. McMillan; E. E. Moore; J. Paris; J. Parke; F. W. Slater; W. J. Smither; D. T. Townsend; J. M. Weir.

1905—H. W. Arens; R. H. Armour; C. B. Aylesworth; G. G. Bell; J. C. Boeckh; A. V. Chase; T. E. Corrigan; M. C. Hendry; C. S. L. Hertzberg; W. G. Hewson; D. W. McKenzie; B. B. Patten; E. F. Pullen; G. L. Ramsey; R. B. Ross; H. V. Serson; D. L. N. Stewart; F. H. Sykes; W. E. Turner; J. M. Vaughan; H. L. Wagner.

1906—G. W. Bissett; M. E. Brian; A. Cameron; M. J. Carroll; A. L. Harkness; R. L. Harrison; S. Hett; W. C. Jepson; T. Jones; J. A. McKenzie; J. A. McPherson; D. W. Marrs; F. F. Montague; W. J. Moore; G. W. Paterson; R. E. Pettingill; W. K. Sanders.

1907—C. C. Rothwell; O. B. Bourne; G. H. Broughton; W. J. Bruce; G. A. Campbell; E. Cavell; A. C. Clendening; R. M. Coleman; C. B. B. Connell; G. P. Coulter; R. Davis; G. A. Dawson; J. S. Galletly; K. Hall; C. T. Hamilton; F. J. Hara; R. A. Hare; H. F. H. Hertzberg; L. W. Klingner; J. A. D. McCurdy; G. MacLeod; W. D. Mackenzie; H. V. Maynard; P. F. Morley; D. G. Munro; J. J. O'Sullivan; F. W. Paulin; H. A. Percy; F. E. Procknow; H. E. Rothwell; A. C. T. Sheppard; H. Southworth; G. S. Stewart; G. F. Summers; J. H. M. Wilkie; J. Young.

BOOK REVIEWS

The Electric Furnace, Its Evolution, Theory and Practice

ALFRED STANSFIELD, D. Sc.

Canadian Engineer, Publishers

This work originated, as the author remarks in the preface, in a series of papers written for the "Canadian Engineer," and is therefore intended to represent in a very simple manner, "the principles on which the construction and use of the electric furnace depend, and to give an account of its history and development."

The first chapter gives a historical review, and the second one is devoted to a description and classification of electric furnaces. In the third chapter the questions of efficiency and of relative cost of electrical and fuel heat are discussed in a way that is not only instructing but also very interesting.

The following table, taken from the work under consideration, gives the net efficiencies of furnaces used for melting metals:

	Per cent.
Crucible steel furnaces, fired with coke	2 — 3
Reverberatory furnaces, for melting metals ..	10 — 15
Regenerated open-hearth steel furnaces	20 — 30
Shaft furnaces (foundry, cupolas, etc.)	30 — 50
Large electrical furnaces	60 — 85

It is evident that the electric furnace is easily first in this respect, and this great advantage is often more than enough to offset the disadvantages from the lower cost of coal as compared with the equivalent amount of electrical energy. It is thus seen that the discussion of the relative cost of electrical and fuel heat for any process, must also involve considerations as to efficiency.

The fourth chapter is entitled "Electric Furnace Design, Construction and Operation." The temperature obtained in a furnace depends not only on the rate of supply of electrical energy, but also upon the rates of radiation and conduction of the heat of the furnace-walls. The temperature finally attained is therefore a point of equilibrium at which the rate of supply is equal to the rate of loss. As these losses are much greater in proportion to the energy consumed when small furnaces are used, the efficiency must increase as the capacity of the unit is increased. The study of the electric furnace in the future, from the point of view of avoiding losses by radiation and conduction, is bound to yield very profitable results.

The recent advances made in the methods of production of iron and steel in the electric furnace, forms the topic of the fifth and most important chapter in the book. The report of the Canadian Commission on European electro-thermic methods of iron and steel production, as well as the more recent report issued by Dr. Haanel on the experimental work at Sault Ste. Marie, have been fully consulted and the remarks made by the author are decidedly optimistic for the future of this industry.

The use of ferro-alloys has become very prominent in recent years, mainly because of their ease of manufacture in electric and crucible furnaces.

In chapter VI the author mentions the alloys with silicon, manganese, chronium, tungsten and vanadium. As the subject of carbide and carborundum furnaces has been exhaustively treated by other writers, a comparatively brief reference is made to these, and the main portion of the chapter is devoted to electro-thermic methods of producing zinc. Amongst other uses of the electric furnace are those for the production of phosphorus, carbon bisulphide, alunderm, caustic soda and aluminum.

"The future development of the electric furnace" forms the subject of the last chapter, and the remarks of the author are very optimistic. Greater efficiency combined with higher temperature are the great assets of this new scientific tool, and in the future as the coal-fields become exhausted, it is most probable that its use will become almost universal in thermal operations.

Regarding the book as a whole, it has been written in a very interesting style, and the "principles" emphasized by the author throughout the chapters are never hidden by too large an array of details, such as often obscure the main thought of many similar works. While not encroaching a great deal on the subject covered by Borchers' Electrometallurgy and Moissan's and Wright's works on the electric furnace, the present work forms a most useful addition to the literature on this topic.

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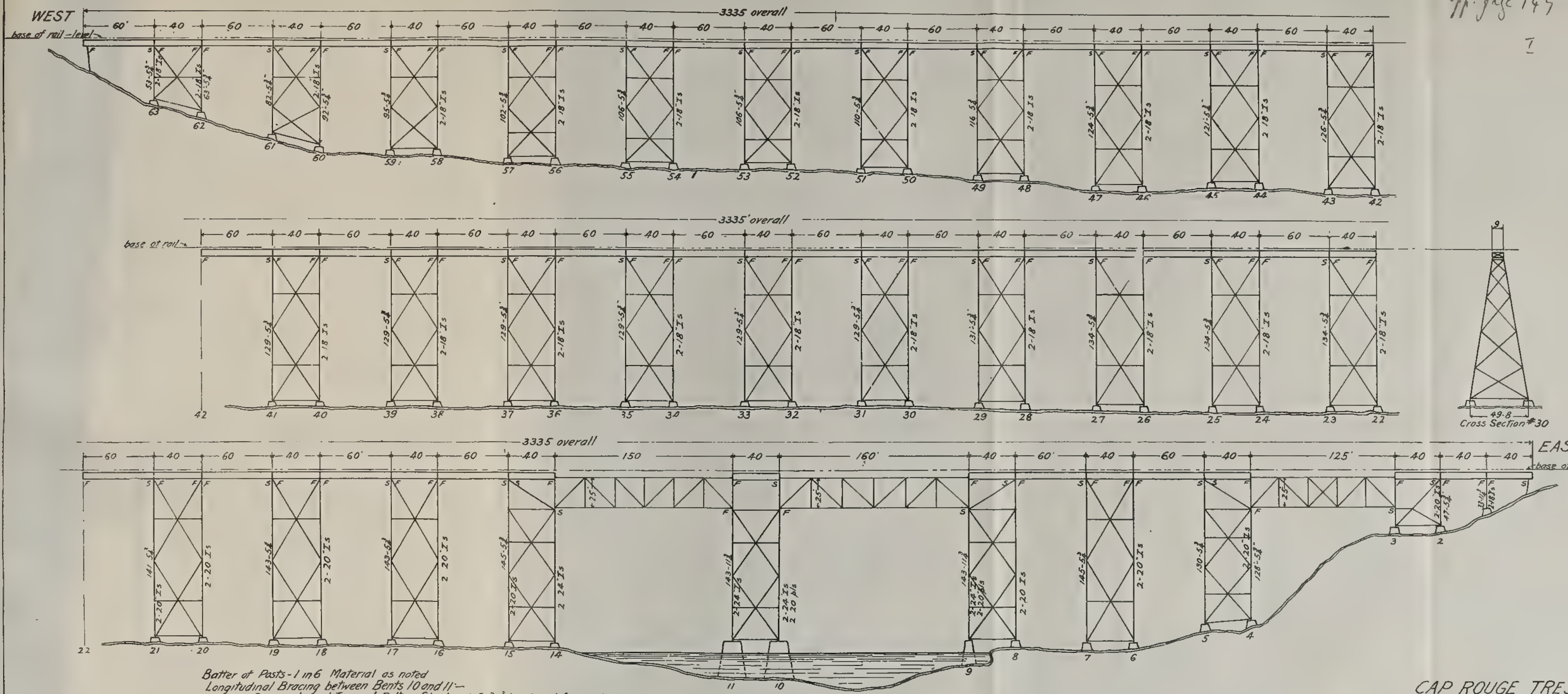
I



Batter of Posts - 1 in 6 Material as noted

Longitudinal Bracing between Bents 10 and 11:—
Diagonals and Top and Bottom Struts - 4 3×3×3/8 Ls laced four sides
Intermediate Struts - 4-5×3×5/16 Ls, laced

Longitudinal Bracing elsewhere —
Diagonals and Bottom Struts - 4-3×2½×3/8 Ls laced four sides.
Intermediate Struts - 4-5×3×5/16 Ls, laced

Sway Bracing:—
Top Struts. Bents 3, 4, 9, 10, 11, and 14 - 2-12" [s laced
Top Struts elsewhere - 2-10" [s laced
Diagonals and Bottom Struts - 4-3×2½×5/16 Ls, laced four sides

NOTE — Fixed ends of spans marked "F"
Sliding ends marked "S"
Heights given denote distances from
base of rail to masonry

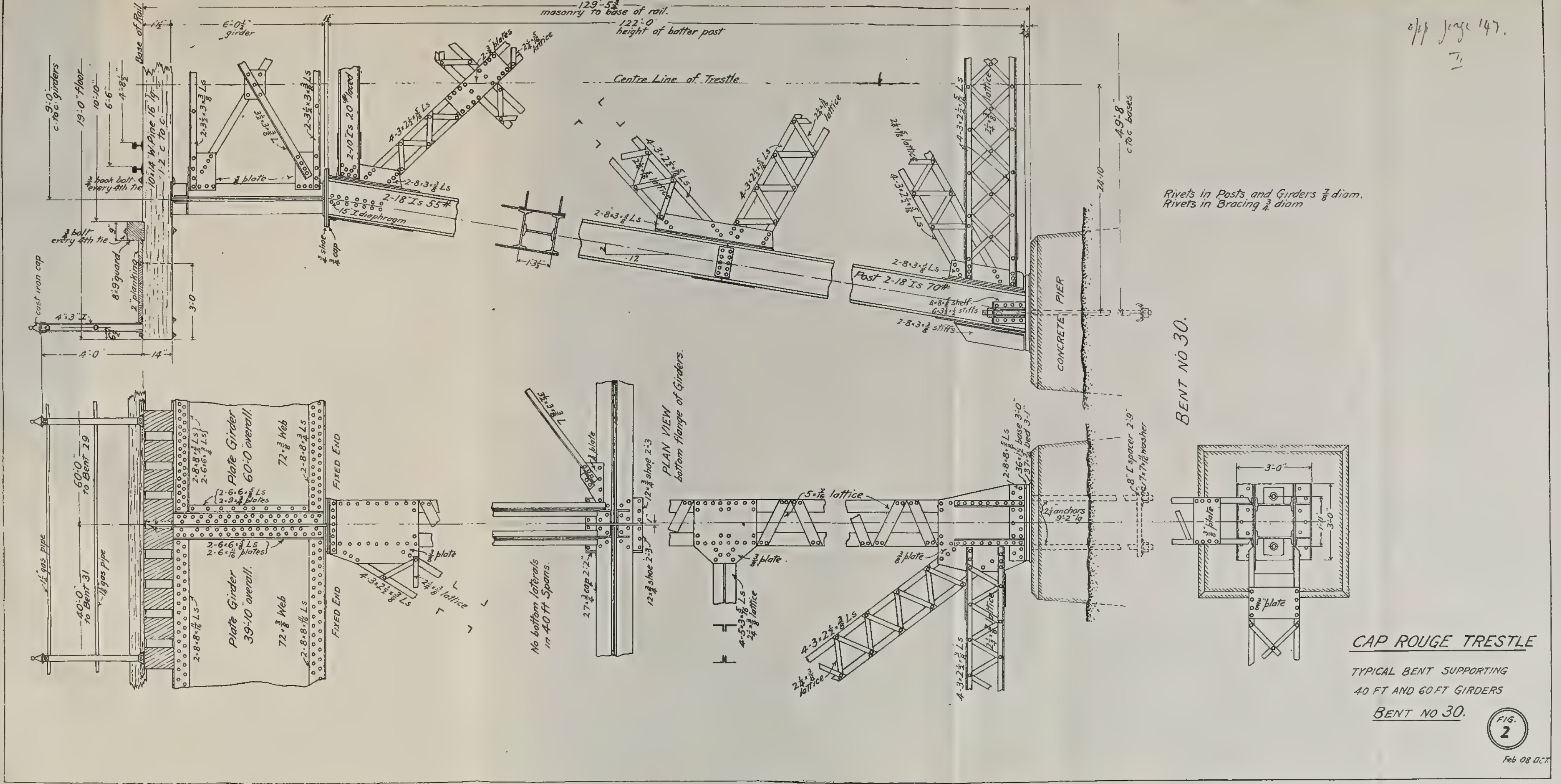
CAP ROUGE TRESTLE

GENERAL DIAGRAM

FIG 1

Feb. 08 D.C.T.

opp page 147.
II



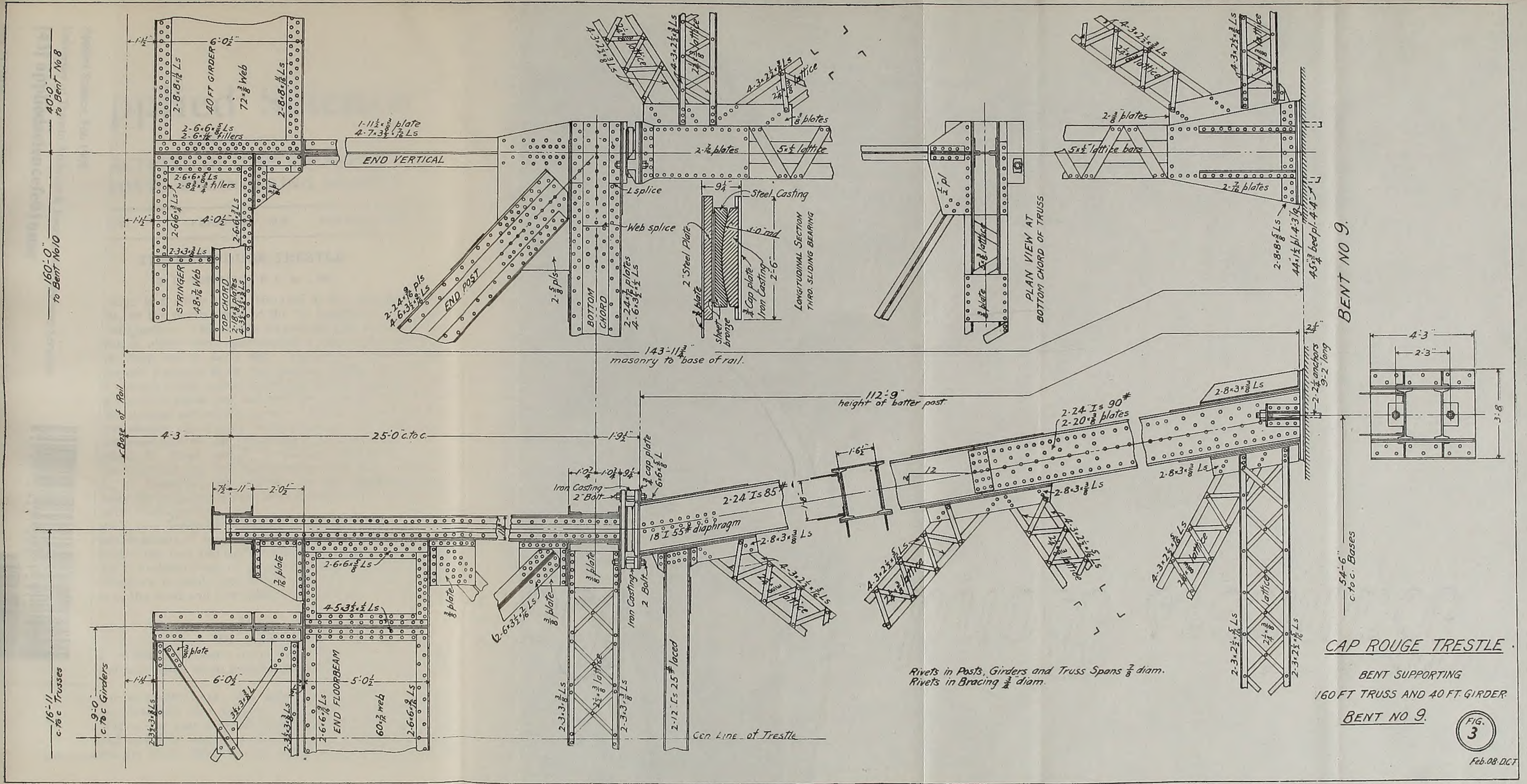
CAP ROUGE TRESTLE

TYPICAL BENT SUPPORTING
40 FT AND 60 FT GIRDERS

BENT NO 30.

FIG. 2

Feb 08 OCT.



Rivets in Posts, Girders and Truss Spans ⅞ diam.
Rivets in Bracing ¾ diam.

CAP ROUGE TRESTLE.

BENT SUPPORTING
160 FT TRUSS AND 40 FT GIRDER

BENT NO 9.

FIG. 3

Feb. 08 DCT